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PERFORMANCE OF CONCRETE BRIDGE DECK JOINTS

Final Report

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Abstract:

The purpose of this research was to investigate the performance characteristics of joints available for use on concrete bridge decks, including primary functions and movement ranges. Eleven reports on joint performance published by state departments of transportation (DOTs) and universities nationwide were analyzed in order to obtain information on joint performance problems typically encountered by state transportation agencies. In addition, American Society for Testing and Materials specifications relevant to bridge deck joints were reviewed, and a nationwide questionnaire survey was also conducted of state DOTs to investigate the state of the practice concerning concrete bridge deck joints.

The research data indicate that the most common deck joint expansion movements are in the range of 1 in. to 4 in. and that strip seal joints are the most commonly specified joint type. The survey respondents placed special emphasis on the importance of proper substrate preparation and adequate anchorage for armor steel, although only five state DOTs require manufacturer representation during joint installation projects to ensure that proper construction procedures are followed. Tearing, snowplow damage, seal separation, and debris accumulation are the most common modes of joint failure. Bridge inspection protocols generally follow the National Bridge Inventory reporting requirements, with inspections performed every 1 to 2 years.

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CHAPTER 1
INTRODUCTION

1.1 PROBLEM STATEMENT

The purpose of this research was to identify the types of joints available for use on concrete bridge decks and to investigate the performance characteristics of each type, including primary functions and movement ranges. Bridge deck joints are used to protect the interior edges of concrete decks from vehicle loads, seal the joint openings, and accommodate concrete deck movements that are produced by temperature changes and creep and shrinkage of concrete. Although the joints are among the smallest components in a bridge structure, the integrity of the whole structure is affected when the joints fail. The Utah Department of Transportation (UDOT) has increasing need for reliable joint treatments to prevent water ingress and subsequent deterioration of bridge components through the corrosive action of deicing salts and to ensure an adequate riding surface for the traveling public.

Many factors contribute to the failure of bridge deck joints. Failure is not necessarily caused by the joint material itself; it can also be caused by careless design, improper installation, and inadequate maintenance. Joint failure is a nationwide problem in the United States; therefore, methods used to remedy joint failure by other state departments of transportation (DOTs) are important considerations in this research. In this project, a literature review was conducted to review performance reports published by other DOTs on concrete bridge deck joints. In past years, UDOT conducted several in-house bridge deck joint experiments in order to evaluate new joint products; these experiments are also reviewed in this report to identify important findings relative to past joint performance on Utah bridges. Furthermore, a questionnaire survey was conducted of state DOTs nationwide to determine the state of the practice for concrete bridge deck joint selection, maintenance, and replacement.

In addition to guidelines utilized by state transportation agencies, test methods and specifications are available through the American Society for Testing and Materials (ASTM). If strictly followed, these specifications should ensure that adequate joint materials are used in bridge deck joint systems. Besides investigating joint materials, UDOT is also interested in identifying and evaluating joint header materials and methods available for use when replacing entire joint systems.

1.2 OUTLINE OF REPORT

This report contains eight chapters. Chapter 1 introduces the research, and Chapter 2 provides an overview of the joint types that are available in the bridge industry, including the primary functions of these joints. In addition, a comprehensive review of joint studies published by researchers at universities and state DOTs nationwide is given in Chapter 3; the chapter provides background information on the performance of both joints and joint headers. Furthermore, reports of in-house experiments on bridge deck joints performed by UDOT between 1992 and 1999 are reviewed in Chapter 4. Additionally, information obtained from a review of ASTM standards is given in Chapter 5 for consideration by UDOT. Numerous important practices employed by transportation agencies for the design, installation, and maintenance of joint systems are highlighted in Chapter 6; if these practices are closely followed, the service lives of bridge deck joints should be maximized. The results of the questionnaire survey are presented in Chapter 7, and conclusions and recommendations are given in Chapter 8 of this report.

CHAPTER 2
TYPES OF BRIDGE DECK JOINTS

2.1 PURPOSE OF BRIDGE DECK JOINTS

Concrete bridge decks experience contraction and expansion as a result of exposure to the environment and the imposition of loads (*1*). If contraction movements are excessively restrained, cracking may occur in the concrete. On the other hand, if expansion movements are restrained, distortion or crushing may result (*1*). One of the means for accommodating contraction and expansion without compromising the integrity of the structure is to provide joints between the bridge deck slabs (*1*).

Bridge deck joints can be classified as either open-joint or closed-joint types (*2*). The ability to allow water and debris to pass through joint openings is the main characteristic distinguishing open joints from closed joints. Because each joint type has advantages and disadvantages, bridge engineers need to be very familiar with the characteristics of the various joints available for use in concrete bridge decks. This chapter presents a comprehensive review of both open-joint and closed-joint types. As the performance of several common joints is discussed in Chapter 3, no attempt is made to compare joints in this chapter.

2.2 OPEN JOINTS

Open joints were primarily designed to permit cyclic and long-term movement, support traffic, pass water and debris, and survive service (*3*). Butt joints (either with or without armor angles), sliding plate joints, and finger joints, which are listed in order of increasing amounts of movement they can effectively accommodate, are the most commonly used open joints (*2*). Details are provided for these types of open joints, as well as for drainage troughs, in the following sections.

2.2.1 Butt Joints

A butt joint, shown in Figure 2.1, is simply an opening between two adjacent slabs of a deck. This joint is usually used to accommodate movements of less than 1 in. or minor rotations associated with thermal movement (*2*). A butt joint, although appearing simple, does require thorough design and proper installation to ensure adequate durability. Armor steel angles are embedded and anchored into the edges of the slabs with studs, bolts, or bars to protect the concrete from spalling and deteriorating. However, the angles are hazardous to traffic when they become dislodged due to insufficient anchorage caused by fatigue of the anchoring elements through time and/or inadequate consolidation of the concrete under the angles during construction (*2*). For further protection, the angles need to be painted regularly to minimize corrosion.

A well-designed butt joint is cost-effective and efficient only under the assumption that the passage of water and debris through the opening will not have adverse effects on the supporting substructures (*3*). Unfortunately, this assumption does not hold true on most modern bridges because of the use of deicing chemicals, which are discussed in the next section; hence, butt joints are seldom used in present practice (*2*).

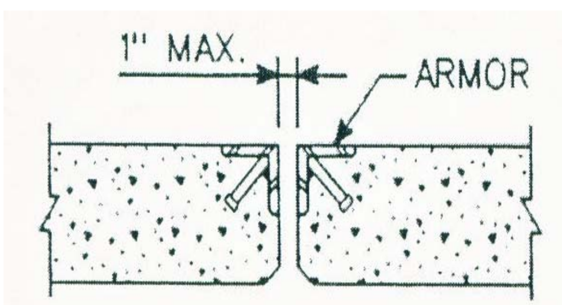

FIGURE 2.1 Armored butt joint (*2*).

2.2.2 Sliding Plate Joints

Sliding plate joints are designed to accommodate movements from 1 in. to 3 in. (*2*). Because sliding plate joints can stop most of the debris from passing through the openings, they were previously considered as closed or partially closed joints. Nevertheless, they are classified as open joints according to modern standards because they are not watertight (*2*). A sliding plate joint is similar to an armored butt joint except that a plate is attached to one side and extends across the opening, while the unattached side rests in a slot and is free to move in the direction of passing vehicles. Figure 2.2 provides a schematic of a sliding plate joint. Movement of the plate can easily be hindered by incompressible debris that accumulates in the slot (*2*). Furthermore, when passing traffic, especially heavy truck traffic, loads the joint, the plate can be pried up and eventually broken. As a result, the impaired plate becomes dangerous for drivers and vulnerable to snowplow damage (*2*). For this reason, sliding plate joints are not suitable on highways with heavy truck traffic.

Inadequate concrete consolidation can cause the plates to become loose very easily under repeated loading by traffic. Construction crews can avoid this problem by ensuring that the concrete is consolidated adequately during the construction phase. Otherwise, the problem is difficult to remedy after bridges are open to traffic (*2*).

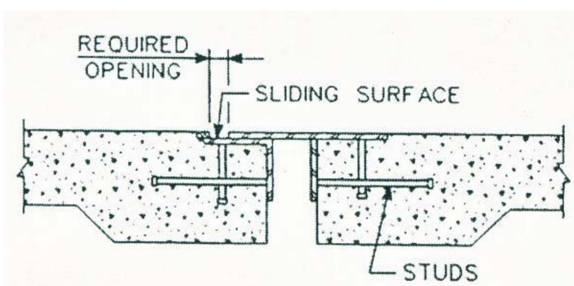

FIGURE 2.2 Sliding plate joint (*2*).

2.2.3 Finger Joints

Finger joints can be used for movements greater than 3 in. (*2*). A finger joint is assembled by anchoring metal plates on the two opposing edges of the joint with cantilevered fingers loosely interlocking each other over the opening (*4*). Figure 2.3 represents a typical finger joint installation.

Finger joints are usually durable but can exhibit a few minor problems. The metal finger plates can become noisy under traffic and can cause a rough

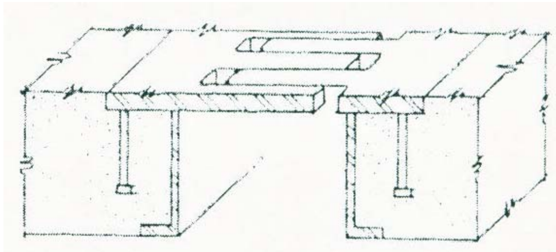

FIGURE 2.3 Finger joint (*2*).

riding surface when they bend under repetitive loading by passing vehicles (*4*). The bent plates can then be broken by snowplows and/or further vehicle traffic. The Pennsylvania DOT suggested that a solution to this problem is to construct the finger plates using metal with high tensile strength (*4*).

2.2.4 Drainage Troughs

Deicing chemicals were first used to melt ice on highways in the United States in 1938 (*5*); their use has increased tremendously ever since. Because of the corrosive nature of deicing chemicals, they can rapidly deteriorate steel and steel-reinforced concrete. The use of open joints does not adequately protect bridge elements from corrosion; instead, the deicing chemicals are permitted to freely pass through the deck openings.

For this reason, open joints are sometimes used in combination with drainage troughs, which are made of non-corrosive materials such as fiberglass or neoprene, to carry and channel away water and debris (*2*). The drainage troughs, however, can experience problems. For example, runoff can overflow onto substructures as a result of debris accumulation in the trough. Regular maintenance, such as cleaning and painting as necessary, is required to keep the drainage troughs functioning properly even when they are installed correctly (*2*).

2.3 CLOSED JOINTS

Preventing the passage of water, deicing salts, and debris through bridge deck joints has become increasingly important in bridge engineering. The challenge is to develop a cost-effective, durable, and watertight joint that can stop water intrusion while still accommodating the anticipated contraction and expansion movements of the decks and providing good riding quality. Many kinds of closed joints have been invented to provide these functions, including poured seals, asphalt plug joints, compression seals, strip seals, reinforced elastomeric joints, and modular elastomeric seals as discussed in the following sections.

2.3.1 Poured Seals

As the name indicates, the poured seal is a pour-in-place sealer. A typical poured seal is shown in Figure 2.4. Poured seals can only accommodate movements of 0.25 in. or less (*3*). Heated asphalt or coal-tar products were previously used to construct poured seals, but silicone is used today (*3*). Modern poured seals generally consist of viscous, adhesive, and pourable waterproof silicone placed near the top of the joint opening. A preformed filler material, or

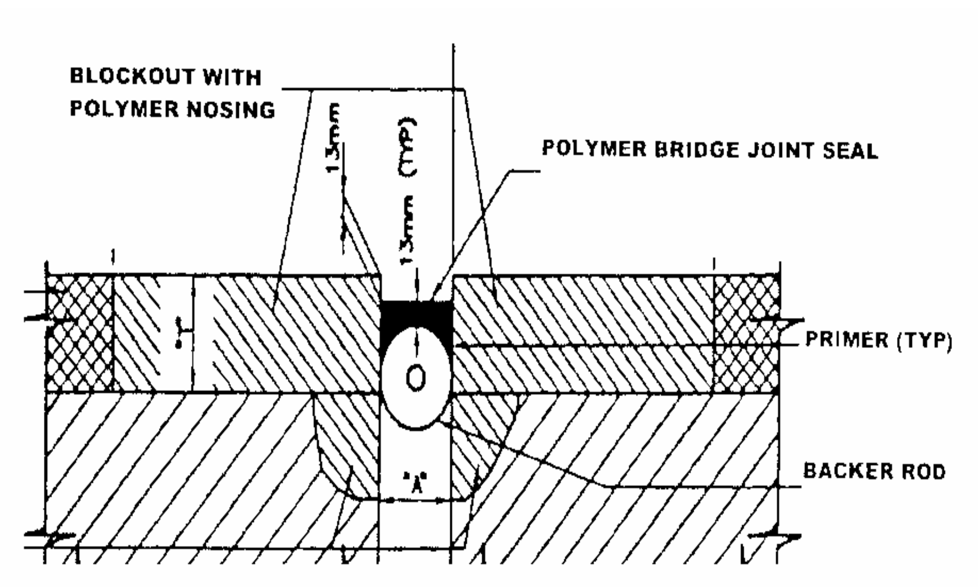

FIGURE 2.4 Poured seal (*2*).

backer rod, is pressed into the opening before the sealant is poured to prevent the sealant from flowing down the joint.

After the sealant cures, it should remain flexible and retain its bond to the concrete joint faces (*3*). Bonding is enhanced when the joint is thoroughly cleaned prior to placement of the sealant (*6*). Also, poured seals work best if the sealant is poured when the ambient temperature is at the middle of the historical temperature range so that the opening is at its midpoint (*2*).

Poured seals are easy to repair, as only the failed portions need to be removed and replaced. Furthermore, repairing poured seals involves minimal traffic delay because it does not require closure of all of the traffic lanes (*7*).

The ratio of the width to the depth of the sealant is called the shape factor, which is a very important parameter in the design of poured seals. When the sealant cross-section changes shape to accommodate contraction and expansion movements of the deck, tensile and compressive stresses, respectively, are induced. The ability of the sealant to withstand these induced stresses depends on its elastic strain capacity, which is a function of the sealant material properties and shape factor (*1*). The sealant strain capacity increases directly proportional to the width and inversely proportional to the depth of the sealant in the joint (*8*).

2.3.2 Asphalt Plug Joints

The asphalt plug joint is a relatively new product that has become popular in some European countries, especially England, for accommodating movements of less than 2 in. (*9*). As illustrated in Figure 2.5, the joint requires a block-out approximately 20 in. wide and 2 in. deep, centered over the joint. A backer rod is pressed into the opening, and the block-out is filled with a modified elastoplastic bituminous binder with mineral aggregate. The binders used for the joint are usually bitumen-modified with plasticizers and polymers to obtain the desired flexibility (*9*). A plate approximately 8 in. wide is placed over the opening to prevent the binder from flowing down the opening.

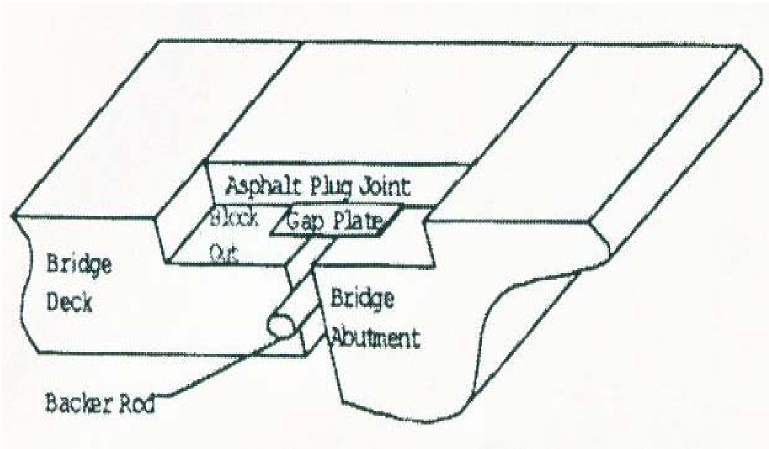

FIGURE 2.5 Asphalt plug joint (*2*).

The asphalt plug joint is attractive because of its ease of installation and repair. Its low instance of snowplow damage and low cost of installation and repair also make it appealing to transportation agencies (*2*). However, the asphalt plug joint may sustain damage when subjected to very rapid changes in temperature (*2*).

2.3.3 Compression Seals

A compression seal is made of either cellular closed-cell foam or, more commonly, semi-hollow extruded neoprene and is usually used to accommodate less than 2 in. of movement. A typical compression seal is shown in Figure 2.6. The seal is pressed into the opening using a lubricant that also serves as an adhesive for bonding the seal in place. The seal must remain in compression throughout its service life to achieve optimum performance (*10*).

The edges of the slabs are usually protected by armor steel angles to prevent spalling. Since the seal relies on compression against the concrete walls or the armor facings to remain watertight, the seal must be sized properly to accommodate the joint movement.

The overall advantages of compression seals are watertightness, relative ease of installation, and cost effectiveness (*11*). The performance of a compression seal depends on the quality of the installation and the selection of

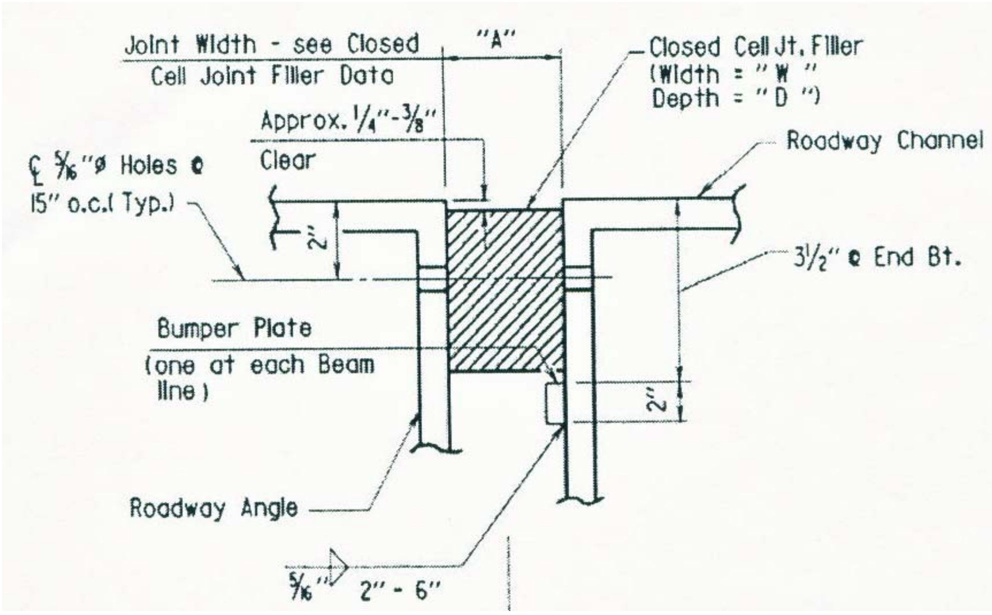

FIGURE 2.6 Cellular compression joint (*2*).

the seal size and material. Some compression seal materials may be ozone-sensitive (*11*).

2.3.4 Strip Seals

As shown in Figure 2.7, a strip seal consists of a flexible neoprene membrane attached to two opposing side rails. The neoprene membrane is pre-molded into a "V" shape that folds as the slabs expand and unfolds as the slabs contract. The joint can accommodate movements up to 4 in. (*2*).

If a strip seal is set too far below the riding surface, incompressible debris can accumulate in the joint quickly. Consequently, the neoprene membrane can be torn, punctured, or pulled from its attachment location when passing traffic impacts the contaminated joint (*12*). Nonetheless, when the strip seal is installed and maintained properly, it has a relatively long service life and adequate watertightness.

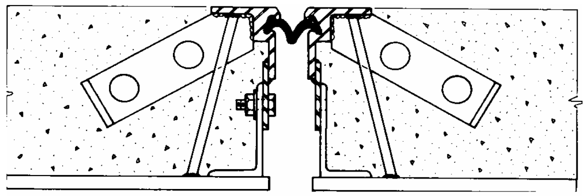

FIGURE 2.7 ACME strip seal (*13*).

2.3.5 Reinforced Elastomeric Joints

Two types of reinforced elastomeric joints are generally available, namely, the sheet seal and the plank seal. Figures 2.8 and 2.9 represent each of the two types, respectively. The sheet seals can accommodate up to 4 in. of movement; the plank seals can accommodate movements from 2 in. to 9 in. but are usually used for movements of less than 4 in. (*13*).

Sheet seals are available in numerous models, which are usually proprietary designs. These include, but are not limited to, Felt Products Corporation's Fel-Span and Pro-Span, Watson/Acme's Elastoflex and Bendoflex, D.S. Brown's Delastiflex, and Structural Accessories' Onflex (*3*). Sheet seals generally have similar construction regardless of the brand name, however. For this reason, details of only the Fel-Span are given in this section.

The Fel-Span consists of 4-ft-long, steel-reinforced neoprene pads with overlapping ends. An epoxy bedding compound is placed on the concrete seat, and the pad is tightened down using cast-in-place studs. A flexible epoxy is spread on the flap of the pad, and the second pad is laid with the undercut end going on top of the flap end of the previous section to create a field splice (*13*). The desirable movement range is from 2 in. to 4 in. (*13*).

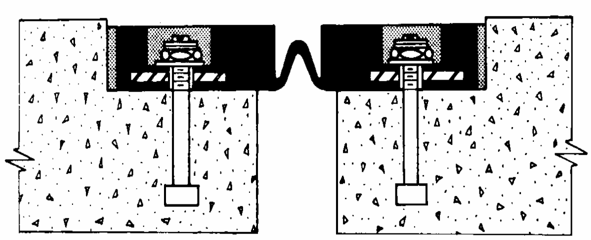

FIGURE 2.8 Fel Span T30 sheet seal (*13*).

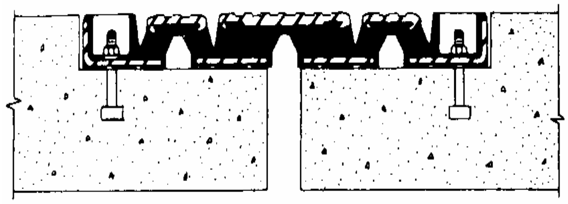

Figure 2.9 Transflex 400A plank seal (*13*).

The plank seal was originally developed by the General Tire and Rubber Company (*3*). Since that time, many kinds of plank seals have been designed, both proprietary and non-proprietary. Some of the modern joints of this type include General Tire's Transflex, Watson/Acme's Waboflex, and Royston's Unidam (*3*). Details of only the Transflex product are given in this section.

The Transflex joint consists of 6-ft-long, metal-reinforced neoprene pads with tongue-and-groove ends. A sealant is spread on the concrete seat in the non-movable portion of the pad, and the pad is bolted down using cast-in-place studs. A flexible epoxy is spread on the tongue-and-groove section, and the second pad is jacked in the transverse direction against the previous pad and bolted down to construct a field splice. The stud wells are sealed with a molded polychloroprene plug (*13*). The desirable movement range is from 2 in. to 6.5 in. (*13*).

Regardless of the type of reinforced elastomeric joint used, reports state that the most important factor contributing to the success of the joint is proper installation (*14*). Contractors should closely follow the instructions provided by the manufacturer to maximize joint service life.

2.3.6 Modular Elastomeric Joints

If a wide range of movement needs to be accommodated, modular elastomeric seals can be utilized. A typical modular elastomeric seal, which is shown in Figure 2.10, can accommodate movements between 4 in. and 24 in., or even 48 in. using special designs (*3*).

The three basic components comprising all modular elastomeric joints are sealers, separator beams, and support bars. Since they all have similar

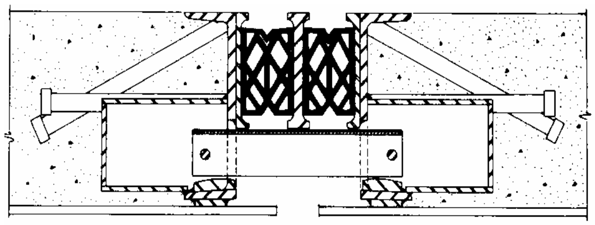

FIGURE 2.10 ACME modular elastomeric joint (*13*).

assembly, they share the same problems, including damage from snowplows, damage to support rails due to fatigue, and damage to the edge rails due to inadequate concrete consolidation.

2.4 SUMMARY

Several types of bridge deck joints can be used to accommodate contraction and expansion of concrete bridge decks without compromising the integrity of the structure, with each type designed for specific situations. The main factors affecting joint selection are watertightness requirements and movement accommodation. Before the use of deicing chemicals, open joints were the predominant types of joints used in the industry because of their low initial costs. Common types of open joints are butt joints, sliding plate joints, and finger joints. Butt joints are generally used to accommodate movements up to 1 in. A movement range between 1 in. and 3 in. can be accommodated by sliding plate joints. For movements greater than 3 in., finger joints are the most suitable to use.

With the increasing use of deicing chemicals during the last several decades, open joints have been progressively eliminated from the industry because of their inability to prevent corrosive materials from passing through the openings and reaching the substructure elements. Indeed, the use of open joints was shown to be a major factor shortening the service lives of bridges. Bridge designers therefore began to require the use of closed joints to seal the openings. Six types of closed joints are typically used in modern bridges. Among the six types, poured seals can accommodate movements up to only 0.25 in. Asphalt plug seals and compression seals can accommodate movements up to 2 in., while strip seals are used for movements up to 4 in. Sheet seals and planks seals can be used when movements are up to 4 in. Modular elastomeric seals accommodate movements from 4 in. to 24 in. and occasionally up to 48 in.

Joint service life can be maximized through utilization of correct construction practices. Proper installation is the most significant factor contributing to joint performance. Also, careful determination of the expected deck movements and informed selection of the types of joints available for use can increase the overall bridge life.

CHAPTER 3
PERFORMANCE EVALUATIONS OF BRIDGE DECK JOINTS

3.1 PERFORMANCE HISTORY

As stated in Chapter 2, open bridge deck joints are prone to cause concrete deck deterioration and corrosion of reinforcing bars and substructures by allowing water, debris, and deicing chemicals to pass through the joint openings. Approximately four decades ago, these problems attracted the attention of bridge engineers and maintenance crews, who began searching for bridge deck joints that could seal the openings and ultimately remedy the deterioration and corrosion problems associated with open joints (*15*). The ability of a bridge deck joint to remain watertight became the most dominant factor in measuring joint performance (*4*).

The first closed joint was used as early as 1914 (*16*). The joint, as shown in Figure 3.1, consisted of a flexible strip of copper sheet metal for spanning the opening and a sealing compound for filling the gap. Very soon transportation agencies found that the method was inefficient and required frequent maintenance (*16*).

In 1936, the B.F. Goodrich Industrial Products Company invented a sealing element having a hollow section. Although this sealing element had marginally improved success over the previous joint, modifications and improvements were still needed (*16*). In 1960, the first compression seal, as shown in Figure 3.2, was developed by the ACME Highway Product Corporation (*16*).

In time, many other proprietary deck joints were also produced and installed. Being used for the first time, however, the joints lacked performance histories. For this reason, state DOTs and universities set up evaluation programs to assess the performance of the newly installed joints. In performing the assessments, they specifically sought to identify the types of joints they should continue to use.

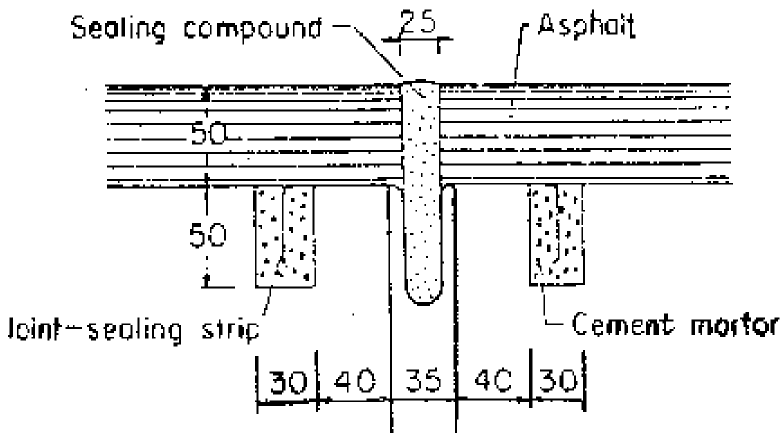

FIGURE 3.1 Design of first closed joint (*16*).

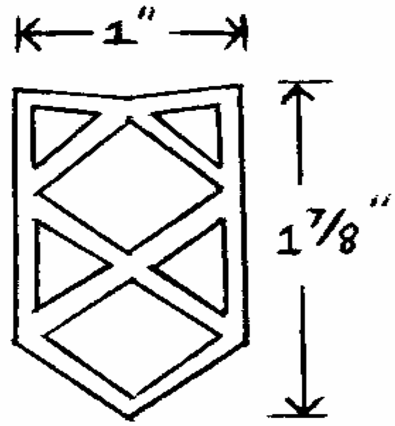

FIGURE 3.2 Design of first compression seal (*16*).

Eleven reports generated from these joint evaluations were identified in the literature and reviewed in this research. A summary of findings is given in this chapter. Consistent with Chapter 2, compression seals, strip seals, reinforced elastomeric joints, and modular elastomeric joints are discussed. In addition, the performance characteristics of finger joints with drainage troughs and joints with elastomeric nosing are addressed.

3.2 COMPRESSION SEALS

Compression seals without armor steel angles were first used in approximately 1960 (*16*). Soon afterwards, bridge engineers and maintenance crews realized that the unprotected concrete adjacent to the openings spalled quite rapidly due to the impacts of heavy traffic. During the next 10 years, modifications were made to install armor steel angles adjacent to the seals. Among the 11 evaluations identified in the literature review conducted in this research, eight included condition assessments of a total of 519 in-service compression seals between the years 1980 and 1990 (*4, 15, 16, 17, 18, 19, 20, 21*). Each inspected compression seal was installed with armor steel angles.

Compression seals can generally be classified as cellular or neoprene (*17*). Cellular compression seals are used primarily at the joint between the bridge deck and the approach slab. At this location, approach slab movement and settlement are the main sources of problems, which include debris accumulation, damaged armor angles and anchorages, concrete spalling, and joint leakage (*17*). In spite of these problems, however, the cellular compression seal is probably the more preferable type because of its comparatively low cost.

Neoprene compression seals received very good ratings in overall performance. Agencies in both Colorado and Ohio reported that the neoprene compression seals performed the best, with only minor leakage problems, among all the joints used (*16, 18*). The Colorado DOT continues to use the neoprene compression seal for movements less than 2 in. because of its durability and low cost. Researchers reported that one of the key advantages of neoprene compression seals is their ease of installation, although this observation does not imply that correct installation procedures can be neglected. Indeed, the Pennsylvania, Maine, and Arizona DOTs reported that problems with their neoprene compression seals were associated with poor construction workmanship (*4, 15, 19*). For example, the seals leaked due to being twisted while they were pressed into place, and the armor steel angles became loose under heavy traffic loads because of inadequate concrete consolidation under and around the armor steel angles.

Even though compression seals are not very susceptible to debris accumulation and snowplow damage, careless installation can increase the vulnerability of the seals to these types of damage mechanisms. For example, if the compression seals are set too far below the riding surface, debris can easily accumulate on the seals. The incompressible debris can then prevent the seals from fully contracting. The Nebraska, Arkansas, and Maryland DOTs observed serious problems of this kind on some of their compression seals (*17, 20, 21*).

On the other hand, if the compression seals are installed above the roadway surface, the seals can be damaged or torn by snowplows and traffic. When the compression seals are damaged or torn, the seals become leaky and thus lose their watertightness. Both the Arizona and Maryland DOTs reported that some compression seals in their jurisdictions were damaged by snowplows to such a degree that the seals needed to be replaced (*19, 21*).

3.3 STRIP SEALS

Many of the strip seals are proprietary products. The types of strip seals reviewed in this research include the ACME, Wabo-Maurer, and Delastiflex MT strip seals. In the literature review conducted in his research, only six reports discussing strip seals could be identified. Among all the evaluations, a total of 206 strip seals were inspected by six agencies during the period between 1980 and 1990 (*4, 13, 15, 16, 18, 20*).

The ACME and Wabo-Maurer strip seals received fair to good ratings by inspectors, except that the Arkansas DOT had some problems associated with poor construction workmanship and manufacturing defects. Both the Pennsylvania and Colorado DOTs stated that they would continue to use strip seals for accommodating movements less than 4 in. (*4, 18*). The only problem the Colorado DOT observed with the strip seals was that the neoprene membranes were very difficult to slip into the grooves of the side rails; however, if the neoprene membranes were correctly installed, the seals exhibited a very high degree of watertightness. The Pennsylvania DOT reported that they would continue to use strip seals for movements less than 4 in. because the seals were cost effective. The only problems the Pennsylvania DOT encountered were very minor, such as noise being produced when traffic crossed the joints, small amounts of leakage, and debris accumulation (*4*).

The ACME and Wabo-Maurer strip seals are the standard joints in Ohio for movements less than 4 in. (*16*). The Ohio DOT inspected 34 strip seals throughout the state and found that they were in excellent condition. The strip seals had a very high degree of watertightness and very good anchorage with only minimal surface damage.

The Maine DOT had both the ACME and Wabo-Maurer strip seals on their inspection list as well. The ACME strip seals performed well in general, with problems limited to minor debris accumulation and leakage, for example, that did not prevent the seals from functioning properly. However, periodic maintenance of the seals was necessary; otherwise, the accumulated incompressible debris would tear the neoprene membranes when heavy traffic traversed the joints (*15*). The two inspected Wabo-Maurer strip seals in Maine had failed. The failure was not related to the neoprene membranes or the side rails, however. Instead, the highway approaches were not paved during the construction phase, and heavy traffic carried gravel onto the seals, causing the seals to be pulled out of the grooves.

The Arkansas DOT, unlike others, had negative experience with using strip seals. They evaluated 26 ACME strips seals and 16 Wabo-Maurer strip seals. Inspectors reported that debris accumulation was severe. In fact, the rate of debris accumulation was so rapid that cleaning was not economically feasible (*20*). Also, inspectors reported that approximately half of the joints had locations where the neoprene membranes were pulled out of the grooves to an extent that the seals were no longer watertight.

The Michigan DOT was the only agency that reported experience using the Delastiflex MT strip seals. Comments given by its inspectors were negative. The major concern was that the seals were very susceptible to snowplow damage even though they were set below the riding surface (*13*). Oftentimes the neoprene membranes were pulled out of the grooves in the side rails. Damage to the neoprene membranes by snowplows progressed with increasing length of service. When the neoprene membranes detached from the grooves, the seals would completely lose their watertightness.

3.4 REINFORCED ELASTOMERIC JOINTS

As with strip seals, most of the reinforced elastomeric joints are proprietary products. They are designed to accommodate movements up to 4 in. Among the 11 reports reviewed, nine of them included reinforced elastomeric joints. A cumulative total of 616 joints were installed and inspected by the nine agencies. The most widely used reinforced elastomeric joints are Fel Span, Transflex, and Waboflex.

According to the reports, reinforced elastomeric joints were more problematic than beneficial to the transportation agencies participating in the evaluation programs. Except for the observation that the joints were effective at minimizing debris accumulation, comments on the joints were all negative (*4, 13, 15, 16, 17, 18, 21, 22, 23*). The Virginia DOT reported that the performance of reinforced elastomeric joints was worse than less expensive joints installed on similar bridges (*22*), and the Maine DOT engineers even considered their reinforced elastomeric joints to be a complete failure (*15*).

Of the 616 reinforced elastomeric joints inspected by the agencies, all except two in Maryland were leaking extensively (*21*). The two Fel Span joints installed in Maryland had been in service for only 2 years at the time of inspection. Also, the traffic volume on the two Fel Span joints was considered to be light, whereas all the other reinforced elastomeric joints were installed on heavily trafficked roads (*21*).

In most cases, the longitudinal butt joints between sections at the locations of field splices were prone to extensive leakage. The Michigan and Nebraska DOTs and the University of Cincinnati reported that leakage at the interface was serious and happened very rapidly after the joints were installed, even though flexible epoxy sealants were used (*13, 16, 17*). The recommended solution to this problem was to reduce the number of field splices by carefully laying out the system during the design phase (*13*).

The interface between the pads and the concrete was another location where leakage occurred. The leakage was most likely due to poor caulking used at the interface, poorly shaped concrete surfaces with which the joint material was in contact, and/or loosening anchor bolts that held the pads in contact with the top of the abutment and deck slab (*15*). The specification for reinforced elastomeric joints was discontinued in Maine due to the extensive leakage problems and relatively high costs of the joint (*15*).

The Pennsylvania, Nebraska, Maryland, and Virginia DOTs reported that the reinforced elastomeric joints were difficult and expensive to install and maintain (*4, 17, 21, 22*). Due to installation difficulty, the joints were often misaligned horizontally and/or vertically. Serious leakage occurred at the misaligned areas on some of the joints in Michigan and Kentucky (*13, 23*). Sometimes the misalignment was caused by inaccurately constructed block-outs in the concrete.

In order to minimize corrosion of the bolts, bolt plugs were previously used to seal the bolt holes. In present practice, the bolt holes are required to be filled with flexible epoxy. However, when heavy traffic traverses the joints, the flexible epoxy bolt plugs can become loose. Consequently, the unfilled bolt holes become another source of leakage and increase the probability of anchor bolt corrosion.

Unlike compression seals, reinforced elastomeric joints are apparently very susceptible to snowplow damage. Except for the two joints installed in Maryland, all of the other inspected reinforced elastomeric joints were damaged by snowplows regardless of the quality of the installation. The Michigan DOT reported that the surfaces of the pads were torn by snowplows so that the reinforcing metal was exposed, creating a potential traffic hazard (*13*). Due to their many performance problems, difficulty of installation, and high initial and replacement costs, reinforced elastomeric joints are not typically recommended by engineers for modern bridge designs.

3.5 MODULAR ELASTOMERIC JOINTS

Modular elastomeric joints are essentially combinations of single compression seals or strip seals (*23*). Greater numbers of single units can be used to accommodate larger movements, typically greater than 4 in. Five agencies with experience using modular elastomeric joints were identified in this research (*4, 13, 15, 21, 23*). A total of 200 modular joints, including ACME, Wabo-Maurer, and Delastiflex DL modular joints, were inspected and evaluated by the five agencies.

The ACME modular joint is available in two models, namely the ACME-ACMA and ACME-BETA. The latter model is a modification of the former one. They are both constructed using a series of single compression seals. Even though the ACME-BETA modular joints are newer than the ACME-ACMA modular joints, some agencies such as the Michigan and Kentucky DOTs are still using the ACME-ACMA product. Both DOTs encountered very similar problems with the performance of this model, with leakage between the compression seals and the steel supports as the first concern (*13, 23*). In Michigan, some joints were found to be leaking over the entire joint length (*13*). The other commonly observed problem was uneven compression of the neoprene modules.

The Maine and Maryland DOTs used both the ACME-ACMA and ACME-BETA modular joints, but their ratings were quite different. The Maine DOT reported that the performance of ACME-ACMA modular joints was poor, while the Maryland DOT said that they performed well (*15, 21*). The joints in Maine were installed in accordance with the manufacturer's recommendations, but they were destroyed by traffic. The inspectors did not know the cause of the poor durability. In Maryland, the joints were in good condition with no snowplow or other damage. Comments on the ACME-BETA modular joints were also different between the two DOTs, except that both reported that debris accumulated in the joints. The Maine DOT reported that the joints were noisy under traffic, while the Maryland DOT found no signs of any loose parts that might potentially cause a noise problem (*15, 21*).

While the ACME joints received mixed reviews, the Wabo-Maurer modular joints were all consistently given similar good ratings by agencies in Pennsylvania, Maryland, and Kentucky. None of the agencies found evidence of leakage. They also observed that no cuts or other damage occurred to the joints if the joints were recessed between 0.125 in. and 0.25 in. below the riding surface (*4, 21, 23*). However, the University of Kentucky reported that if the joints were set too far below the riding surface, debris would accumulate in the cavity. If too much debris accumulates in the joints, the probability of the modules being punctured increases. Researchers also observed that as the number of single strip seals increased, vertical misalignment of the support bars became problematic. Consequently, noise and ride discomfort were produced, and uneven compression of the neoprene modules also occurred (*23*).

As with the Delastiflex MT strip seals, the Delastiflex DL modular joints did not receive good ratings (*4, 13*). Evaluations were performed on eight Delastiflex DL modular joints, among which three were evaluated by the Pennsylvania DOT and the other five by the Michigan DOT. The greatest concern was that the Delastiflex DL modular joints were very susceptible to snowplow damage (*4, 13*). Some neoprene materials had been damaged so severely that they needed to be replaced. However, the replacement was no less resistant to snowplow damage due to its equally high elevation above the deck surface (*13*). The excessive exposure of neoprene material surfaces also made the joints unsuitable for installation in areas requiring the use of snowplows. In many cases, Delastiflex DL modular joints were found to be leaky soon after installation. Due to the poor performance of these joints, their installation difficulty, and their high initial cost, the Michigan DOT decided to stop using Delastiflex DL modular joints after the evaluation.

When modular joints were invented, designers were desirous to replace conventional finger joints. Unfortunately, however, researchers reported, “Experience with these systems shows that, while some of these expensive systems have performed fairly well, most have had problems no less troublesome than those they were supposed to eliminate when using the conventional finger dam systems” (*4*). Many transportation agencies have therefore returned to using finger joints, placing more emphasis on drainage troughs (*2*). For this reason, reports on the performance of finger joints with troughs were also reviewed in this study. A summary is given in the following section.

3.6 FINGER JOINTS WITH TROUGHS

Finger joints were designed to accommodate movements greater than 3 in. (*2*). Among the 11 reports reviewed in this research, only three, which were authored by the Maine, Arkansas, and Pennsylvania DOTs, reported on the performance of finger joints. These agencies had a total of 41 finger joints in service within their jurisdictions. Most of the ratings of the 41 joints were good; the few low ratings were due to poor construction.

The Maine DOT evaluated four finger joints, and all four joints performed well. The joints had been in service from 6 to 22 years. One maintenance manager remarked that this type of joint is the best in service (*15*). On structures with large skews, the heavy finger joints were observed to keep the structure in alignment; the movement of the structure destroyed other types of joints (*15*). While many other types of joints were susceptible to snowplow damage, finger joints appeared to be very durable relative to snowplow damage. The finger joints also fulfilled one of the main purposes and functions of bridge deck joints by providing smooth transitions across deck slabs in terms of ride quality (*15*). The only concern the Maine DOT had with finger joints was ice build-up in the troughs. The built-up ice would restrict joint movement. No suggestion on how to prevent ice from building up in the troughs was provided, however.

The Arkansas DOT evaluated 15 finger joints that had been in service from 6 to 13 years (*20*). That report stated that finger joints with neoprene or metal gutters provided the best performance (*20*). The watertightness performance rating of the finger joints with troughs was in most cases excellent. The only problem with finger joints reported by the Arkansas DOT was debris accumulation (*20*).

The Pennsylvania DOT evaluated 22 finger joints that had been in service from 1 to 18 years (*4*). The report stated that the 22 finger joints had average performance ratings higher than the ACME, Delastiflex DL, and Wabo-Maurer modular joints (*4*). Problems the Pennsylvania DOT had with finger joints were mostly due to poor construction. Horizontal misalignment during construction caused the fingers to jam when the joint closed upon deck expansion, while vertical misalignment caused poor ride quality, noise, and sometimes bending or breakage of some fingers. The other problem related to poor construction was blockage of the joints by debris accumulation. The authors of the report observed that this problem arose when the trough did not have sufficient slope to drain the contaminated water and flush the loose debris before it had a chance to accumulate and harden. The Arkansas DOT stated, "When a finger joint had a trough sloping at eight percent, there was no debris accumulation six years after placement, but when the trough had a slope of one percent it was filled with debris in six months" (*20*). The problem of debris accumulation can also be alleviated by periodic maintenance. All three DOTs said that the neoprene or metal troughs generally require cleaning on an annual basis (*4, 15, 20*).

The Pennsylvania DOT also observed that the fingers in the finger joints could sometimes be bent or even broken under the continuous loading of heavy traffic (*4*). They suggested that fingers should be designed with sufficient tensile strength, well aligned, and properly anchored during construction to minimize bending and breaking.

Even though the Pennsylvania DOT engineers encountered the problems with finger joints mentioned above, they continued to use finger joints for movements over 4 in. because, based on a comparison of initial costs and general performance, finger joints were the most cost effective.

Based on the reports given by the three agencies on the performance of finger joints, the joints should perform according to design and better than most types of modular joints if the joints and the trough are installed correctly, periodic maintenance is performed at least once a year, and ice is prevented from building up in the troughs.

3.7 ELASTOMERIC NOSING MATERIALS

While steel-armored bridge deck joints function well at times, steel angles can cause performance problems. Therefore, some transportation agencies have experimented with elastomeric concrete as a replacement for armor steel angles, as elastomer technology has developed rapidly since 1980. The Florida DOT conducted a 2-year bridge deck joint evaluation program that began in the spring of 1993 and concluded in December of 1995 (*24*). The purpose of the program was to assist bridge engineers in Florida with selecting expansion joint systems. Ratings of the selected joints were based on four components: performance evaluation, load test evaluation, installation and maintenance evaluation, and overall product evaluation by the state materials office. The test included joint sealants, compression seals, strip seals, and buried joint systems installed with steel armor or elastomeric nosing. The following are the joint sealants and systems evaluated in the program:

1. Chemcrete 1000 Expansion Joint System
2. Delcrete Elastomeric Concrete/Steelflex Strip Seal System
3. Dow Corning 902 RCS Joint Sealant
4. X.J.S. Expansion Joint System
5. Ceva 250 Joint System
6. Ceva 300 Joint System
7. Evazote 380 ESP
8. Jeene Structural Sealing Joint System (PC35)
9. Jeene Structural Sealing Joint System (PC92M)
10. Sylcrete 10-Minute Joint Sealant
11. Resurf IV
12. Expandex Buried Joint System
13. Wabocrete ACM Expansion Joint
14. Koch 2000 SL Bridge Joint Sealant
15. Koch BJS Joint System
16. Flexcon 2000 Joint Sealing System

17. Techstar Elastomeric Strip Seal

Among these 17 joint sealants and systems in the project, only the Koch BJS and Expandex Buried Joint System are asphalt plug joints. Four of the products are sealants, including the Dow Corning 902 RCS Joint Sealant, Evazote 380 ESP, Koch 2000 SL Bridge Joint Sealant, and Sylcrete 10-Minute Joint Sealant. The other 10 products are complete joint systems.

From the results of the 2-year evaluation program, the following joint sealants and joint systems were approved for use in Florida:

1. Dow Corning 902 RCS Joint Sealant (poured silicone seal with armored edges)
2. X.J.S. Expansion Joint System (poured silicone seal with polymer block-out)
3. Ceva 300 Joint System (closed-cell compression seal with armored edges)
4. Expandex Buried Joint System
5. Koch BJS Joint System
6. Delcrete Elastomeric Concrete/Steelflex Strip Seal System (strip seal with polymer block-out)
7. Jeene Structural Seal (seal only, not the system).

Among these seven approved systems, the X.J.S. Expansion Joint System and the Delcrete Elastomeric Concrete/Steelflex Strip Seal System, which are shown in Figures 3.3 and 3.4, respectively, were installed with elastomeric nosing. The X.J.S. Expansion Joint System utilized the Silspec 900 NS nosing, which is a tough, wear-resistant polymer. The Delcrete Elastomeric Concrete/Steelflex Strip Seal System consisted of a Delcrete block-out, which is a polyurethane-based material designed to develop high strength and bond easily to a variety of substrates.

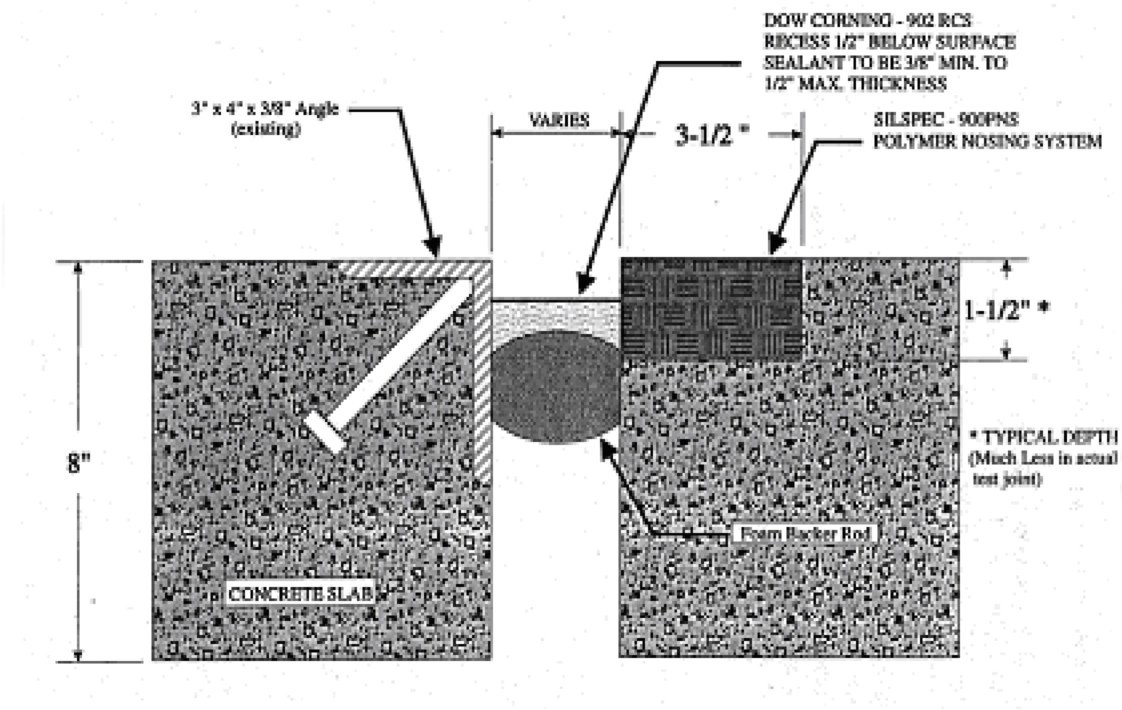

FIGURE 3.3 X.J.S. expansion joint system (*24*).

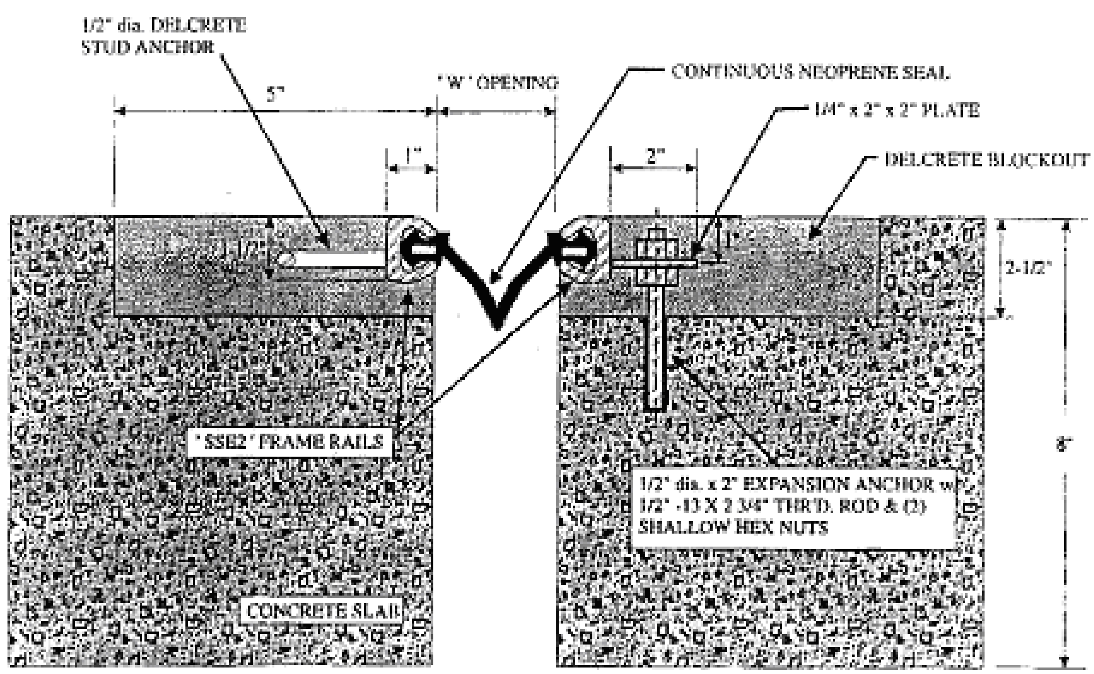

FIGURE 3.4 Delcrete elastomeric concrete/Steelflex strip seal system (*24*).

3.8 SUMMARY

Concrete deck deterioration and corrosion of reinforcing bars and substructures due to the intrusion of water, debris, and deicing chemicals are significant factors in overall bridge performance. As a solution to these issues, closed joints have been increasingly used to replace conventional open joints in order to seal deck openings. Watertightness is now widely recognized as an important joint characteristic.

Among the three types of closed joints commonly used in the United States for accommodating small movements, reinforced elastomeric joints are not recommended by most of the agencies that have experience with them. Reinforced elastomeric joints are susceptible to snowplow damage, making them unsuitable for locations where snowplows are used. These joints are also difficult and expensive to install and maintain. They are not cost effective since the performance of these joints is generally worse than the performance of other functionally similar joints that are less expensive. All of these shortcomings of reinforced elastomeric joints caused them to be eliminated from common use.

For movements less than 2 in., compression seals with armor steel angles are recommended. The installation cost of compression seals is low compared to other types of joints. They can be installed without significant difficulty; however, the installation must be performed correctly to ensure good performance. During construction, concrete around and under the armor steel angles must be adequately consolidated, and the seals must not be twisted during installation.

Many agencies recommend continued use of strip seals for movements less than 4 in., except the Delastiflex MT model. This model is not recommended because it is very susceptible to snowplow damage even if it is set below the riding surface. The other strip seal models perform very well with only minor leakage problems. As with compression seals, care must be taken when installing the strip seals. Components most sensitive to construction errors are the neoprene membranes and the grooves in the side rails. If the neoprene membranes are not slipped into the grooves tightly, they can be detached by snowplows or traffic very easily.

Modular elastomeric joints are designed to accommodate deck movements larger than 4 in. However, they can exhibit numerous problems, including leakage, damage from snowplows, damage to the neoprene sealant material, and damage to the supports. Among the three common types of modular joints, the Delastiflex DL modular joints perform the worst. Characterized by numerous problems, modular joints do not presently appeal to bridge engineers. Until modular elastomeric joints can be improved adequately, finger joints are the type most bridge engineers prefer to use for large movements. If finger joints are installed carefully, maintained periodically, and provided with drainage troughs having sufficient slope, they can provide a high level of performance for many years.

Steel armor angles often become dislodged and thus become leaky and hazardous to traffic. To avoid these problems, some transportation agencies utilize elastomeric concrete nosing instead of armor angles. The evaluation performed by the Florida DOT suggests that the X.J.S. Expansion Joint System with the Silspec 900 NS nosing and the Delcrete Elastomeric Concrete/Steelflex Strip Seal System with the Delcrete block-out can be successfully used to replace conventional joints with steel armor angles.

CHAPTER 4
UDOT EXPERIMENTAL JOINT EVALUATIONS

4.1 IN-HOUSE UDOT RESEARCH

According to information provided by UDOT, five in-house experiments on bridge deck joint systems, which were performed between 1992 and 1999, have been recorded. In these experiments, UDOT endeavored to identify new joint products that met required standards while attempting to replace failed systems. However, not every new product performed satisfactorily. Even though some of the new products performed well, only a few were later included in the UDOT standard specification for bridge deck joints.

The following sections present a brief summary of each of the five joint products evaluated by UDOT, including the Koch-Bestway bridge joint repair system, the Dow Corning 902 RCS silicone joint sealant, the Silspec 900 PNS polymer nosing system with Dow Corning 902 RCS silicone joint sealant, the Sikaflex 15LM low-modulus elastomeric polyurethane joint sealant, and the Flexcon 2000 joint sealant system with Flexcon A/C nosing.

4.2 KOCH-BESTWAY BRIDGE JOINT REPAIR SYSTEM

The first joint on the west abutment of bridge F-298 located eastbound on Interstate 80 at Parley's Summit failed and needed to be replaced. A Koch-Bestway bridge joint repair system was installed by Koch-Bestway of Greeley, Colorado, on April 2, 1992. The new joint system required 2 days to install and was inspected once a year for 3 years after installation.

The first inspection was made in April of 1993, by which time failure had already occurred. The supplier of the joint requested that another joint be installed and claimed that the previous installation was performed incorrectly. The supplier was allowed to replace the failed joint at no cost to UDOT outside of traffic control. The new joint was installed on July 12, 1993, and it was also inspected once a year. In July of 1995, the inspectors agreed that the joint was performing well enough to be approved.

4.3 DOW CORNING SILICONE JOINT SEALANT

When the original joint on the bridge located 1 mile east of Interstate 15 on State Route 175 failed, a Dow Corning 902 RCS silicone joint sealant was installed in conjunction with a large backer rod as a replacement. This new joint seal material was evaluated for adhesion and durability on 6-month intervals to investigate its potential utility for future bridge joint repairs.

On May 11, 1992, UDOT evaluated this silicone joint repair and found that the material had been pulled away from the receptacle gland. Because the joint system failed in less than 6 months, the inspector recommended that UDOT continue to consider other types of bridge deck joints.

4.4 SILSPEC POLYMER NOSING SYSTEM WITH DOW CORNING SILICONE JOINT SEALANT

The eastbound lane of bridge C-629 on Interstate 215 at mile post (MP) 16.69 required bridge deck joint repairs in 1993. The joint system used to repair the failed one consisted of the Silspec 900 PNS polymer nosing system with the Dow Corning 902 RCS silicone joint sealant. Visual inspections of both materials were performed once every 3 months in the first year and once every 6 months in the second year. During each inspection, joint leakage; bonding between the nosing material, substrates, and joint sealant material; distresses in the nosing material and silicone sealant; and overall performance of the materials were observed.

Final inspection was performed by UDOT on October 12, 1994. The joint system showed no signs of leakage, the bonding of the Silspec 900 PNS polymer nosing to the concrete substrate and the bonding of the joint sealant material to the nosing material "looked good," the nosing material showed no signs of distress, the joint sealant material was soft and pliable, and the overall performance of the materials was good. Since this repair joint system was successful, it was approved for future use on similar structures.

4.5 SIKAFLEX LOW-MODULUS ELASTOMERIC POLYURETHANE JOINT SEALANT

Until 1994, the silicone joint sealant was the only joint system listed in the UDOT standard specification. Ten Sikaflex 15LM low-modulus elastomeric polyurethane joint sealants, which were installed by Sika Corporation on October 12, 1994, on northbound Interstate 15 at approximately MP 207.5, were evaluated to determine whether the products could be added to the UDOT standard specification. The joints were inspected every 6 months for at least 5 years. The performance of the new joints was compared with the silicone joint sealants installed in an adjacent lane.

In September of 1997, only the third year of a 5-year guarantee, five of the 10 joints showed elongation failure, and the evaluation team agreed that the performance would worsen through time since stretch marks in the joint seal material were already present. This final evaluation suggested that these Sikaflex joint sealants could not be approved for inclusion in the UDOT standard specification.

4.6 FLEXCON 2000 JOINT SEALANT SYSTEM WITH FLEXCON A/C NOSING

A Flexcon 2000 joint sealant system with Flexcon A/C nosing material was used to replace a failed joint system on bridge C-745 over the Green River along State Route 45 at MP 32.74. After the installation, visual inspection of the materials was performed once every 3 months during the first year and once every 6 months during the second year.

After two inspections had been performed, the UDOT Structures Division reported that no signs of failure were observed in either evaluation and decided that the Flexcon 2000 joint sealant system was an acceptable bridge joint repair system for future use on similar structures.

4.7 SUMMARY

Among the five bridge deck joint products evaluated by UDOT between 1992 and 1999, three performed satisfactorily and were permitted for future use on similar structures. The three approved systems were the Koch-Bestway bridge joint repair system, the Silspec 900 PNS polymer nosing system with the Dow Corning 902 RCS silicone joint sealant, and the Flexcon 2000 joint sealant system with Flexcon A/C nosing material.

The UDOT reports documenting experimental evaluations of specific bridge deck joint products could have been more useful as future references if additional information had been provided. In order to properly document experiments for future reference, UDOT should include the average daily traffic (ADT) of the bridges during the year of testing, the anticipated joint movements that need to be accommodated, the reason for repairing or replacing the existing joints, and the procedures utilized for selecting specific products for evaluation. Furthermore, the contact information of the person who was in charge of the project, as well as the manufacturer representative who installed the joint, should be given for future inquiry. With this additional information, engineers making future decisions about joint replacements for similar structures can refer back to the reports and find meaningful data.

Besides increasing the amount of engineering data provided in reports about experimental products, UDOT should establish a consistent evaluation program. For example, inspections of experimental joints should follow a standardized checklist of relevant performance characteristics, including but not limited to debris accumulation, adhesion and cohesion of joint materials, condition of anchorages and/or header materials, watertightness of the joints, condition of the concrete edges of the deck joints, deterioration of substructures, riding quality, noise level under travel, and general appearance of the joints. With a consistent evaluation program, UDOT should be able to achieve greater objectivity and reliability in the process of approving new joint products for inclusion in the UDOT standard specification.

CHAPTER 5
STANDARD SPECIFICATIONS AND TESTS

5.1 SOURCES OF SPECIFICATIONS AND TESTS

Bridge deck joint companies often claim that their products are durable and can withstand various traffic and environmental conditions. However, as described in Chapters 3 and 4, many products perform unsatisfactorily and fail prematurely. Specifications and tests are therefore necessary to assess the performance qualities of bridge deck joints. Unfortunately, among all types of joints used today, only poured seals, compression seals, and strip seals have such specifications and tests available for assessing and controlling their characteristics. Even though specifications for poured seals are described in the ASTM standards, results from research and laboratory testing show that the specifications and test methods may not effectively identify poor sealants (*7*). Therefore, some modifications to the test methods for poured seals have been recommended by researchers. No studies on the effectiveness and accuracy of the specifications and test methods for compression seals or strip seals were identified in the literature; therefore, the tests outlined in the ASTM standards are apparently the only methods available for evaluating those kinds of seals.

Adhesive lubricants are often used to facilitate the installation of both compression seals and strip seals. The ASTM standards also describe tests designed to evaluate whether the adhesive lubricants will function properly. The specifications for poured seals, compression seals, strip seals, and adhesion lubricants are discussed in the following sections.

5.2 POURED SEALS

Specifications and test methods for poured seals are not readily available in the ASTM standards. The most relevant standard is ASTM C 719, Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants under Cyclic Movement (Hockman Cycle). However, this test method particularly addresses building seals and sealants, which have less rigorous performance requirements, so inadequate poured seals may pass the test and be mistakenly approved for installation on bridge decks. Therefore, in order to improve performance predictions of poured seals installed on bridge decks, researchers have modified the test methods based on the results of laboratory testing (*7*). The modifications are suitable for use in states that have climates similar to the state of Wyoming. All recommendations are based on a 0.5-in. sealant width (*7*). The proposed sealant evaluation process consists of specimen preparation, sealant curing, and testing as described in the following sections. Criteria for sealant selection are also discussed.

5.2.1 Specimen Preparation

The dimensions of mortar briquettes and sealant specimens should follow the recommendations outlined in ASTM C 719. Cement should be Type III Portland Cement conforming to ASTM C 150, Standard Specification for Portland Cement. Fine aggregate should be sand conforming to ASTM C 33, Standard Specification for Concrete Aggregates. The 3-in. by 2-in. by 1-in. mortar cubes should be cast in accordance with ASTM D 1985, Standard Practice for Preparing Concrete Blocks for Testing Sealant for Joints and Cracks. After the cubes are cured, a dry diamond blade should be used to saw the mortar cubes in half to a final dimension of 3 in. by 1 in. by 1 in. The use of a dry diamond blade in this laboratory test replicates actual joint installation on a bridge deck.

After the mortar briquettes are formed, they should be cleaned using pressurized water to remove concrete dust and other debris. Then, both joint faces should be sandblasted and cleaned with a blast of compressed air (*7*). When the briquettes are completely dry, the two halves should then be sealed as described in ASTM C 719. Whether a primer is used prior to sealing is dependent on the sealant manufacturer's recommendations.

5.2.2 Sealant Curing

ASTM C 719 outlines the curing and conditioning environment for both single- and multi-component sealants. Standard conditions in this test are defined as a temperature of 73 ± 4°F and a relative humidity of 50 ± 5 percent. For single-component sealants, the curing period consists of 7 days at standard conditions, followed by 7 days at 100 ± 4°F and 95 percent relative humidity, followed by 7 days at standard conditions. Multi-component sealants should be cured at standard conditions for 14 days only. After the curing period, both the single- and multi-component sealants should be immersed in distilled or deionized water for 7 days and then placed in a 158°F oven under compression for 7 days.

The heat-aging process is designed to determine the amount of compression set a sealant will experience. The more compression set a sealant experiences, the more strain capacity it loses. Therefore, the curing and conditioning process specified in ASTM C 719 is necessary to determine whether the sealants can accommodate joint movements during the hottest summer days. However, some test results show that the heat-aging process will improve the adhesion strength of certain kinds of sealants. For this reason, tests should also be performed with the water immersion and heat-aging steps omitted (*25*). Sealants without heat aging are representative of installations in the fall (*7*). All the sealant specimens to be cured without subjection to the water immersion and heat-aging steps should be placed at standard conditions for 14 days after curing. These specimens can then be tested with the sealants that have experienced the water immersion and heat-aging processes at the same age on the 35th day and the 28th day after fabrication for single-component and multi-component sealants, respectively.

In addition to the two curing and conditioning environments mentioned above, single-component sealants should also be cured at standard conditions for 21 consecutive days, followed by subjection to standard conditions for 14 days in order to be tested together with other single-component sealants on the 35th day. Removal of the 7-day period of elevated temperature conditions and humidity in this case is performed because the curing time for most single-component sealants is mainly dependent on the amount of moisture in the atmosphere. The curing condition in this testing scenario is intended to simulate the curing of sealants in dry climatic areas, such as Utah, where longer curing time is required than in humid areas (*7*).

5.2.3 Testing

The original test method specified in ASTM C 719 requires subjection of the sealant specimens to compression and extension cycles; however, researchers observed that this method is unable to accurately test the strain capacity of the field-molded bridge joint sealants (*7*). The sealants should instead be subjected to pure tension until failure instead of cyclic compressive and tensile strains. Tests should then be performed at two different temperatures, the standard temperature as outlined in ASTM C 719 and –40°F (*7*). Three specimens for each curing and conditioning environment described in the previous section should be tested at each temperature.

5.2.4 Sealant Selection

Guidelines for sealant acceptance are based on sealant strain capacity (*7*). To evaluate sealant strain capacity, results from the tension test on specimens cured in accordance with ASTM C 719, including the water immersion and heat-aging steps, should be used. The test conducted at –40°F represents the worst scenario, where the sealants are strained to their maximum extension in the winter after experiencing compression set during the summer. In order to pass the test, the sealant must exhibit a minimum of 100 percent strain before failure.

To evaluate sealant adhesion strength, tension tests should be performed on single-component sealant specimens cured for 21 days at standard conditions and on multi-component sealant specimens cured for 14 days at standard conditions. As mentioned earlier, specimens are not immersed in water nor heated in an oven because heat aging may increase adhesion strength. Results from testing at standard conditions and at –40°F should be used to determine the adhesion strength. In order to pass the test, a given sealant must exhibit a minimum of 200 percent strain without detaching from the mortar briquettes.

Researchers also suggest that the length of time for a sealant to cure should be limited because the amount of time a lane needs to be closed is an important construction issue. The time for a sealant to develop a top skin should be less than 6 hours, and the time required from joint face preparation to trafficking should be limited to 24 hours (*7*).

5.3 COMPRESSION SEALS

Numerous performance characteristics for compression seals are described in ASTM D 3542, Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Bridges. The specification is only applicable to seals in which the height exceeds 90 percent of the nominal width. Material properties evaluated for qualifying compression seals for use in bridge joint systems include recovery, compression-deflection properties, tensile strength, durometer hardness, oven aging, oil swell, and ozone resistance. Brief explanations of these tests are given in the following sections.

5.3.1 Recovery

Both high- and low-recovery tests are used to determine the degree of recovery of a compression seal after it has been compressed to 50 percent of its nominal width for a specific amount of time under extreme temperatures. The percentage of recovery should be calculated using Equation 5.1:

$$R = \frac{w_r}{w_n} \cdot 100 \tag{5.1}$$

where R = recovery, %

w_r = recovered width, in.

w_n = nominal width, in.

According to the test protocol, a total of six specimens are prepared by cutting and buffing a sample of preformed seal. Two of them are used for the high-recovery test, and the remaining four are used for the low-recovery test. Tooth-blade devices or guillotine-type cutters cannot be used for specimen trimming because they eliminate natural irregularities that affect the bonding between the sealant and the concrete face. Also, when the samples are buffed, care should be taken not to overheat the specimens.

Specimens should be deflected to 50 percent of their nominal width using the assembly specified in Method B of ASTM D 395, Standard Test Methods for Rubber Property—Compression Set. For the high-recovery test, two compressed specimens are placed in an oven conforming to ASTM D 573, Standard Test Method for Rubber—Deterioration in an Air Oven, for 70 hours. The oven should be capable of maintaining a temperature of 212 ± 2°F. The specimens should not be preheated. After the test, the compressive force is removed, and the specimens are allowed to recover at 73 ± 4°F for 1 hour before the recovered width is measured. ASTM D 3542 requires 85 percent of high recovery.

According to ASTM D 3542, compression seals should be tested in two conditions for the low-recovery test, 14 ± 2°F for 72 hours and –20 ± 2°F for 22 hours. Two specimens should be tested under each of the two conditions. For each condition, two compressed specimens are placed in a refrigerated box to maintain the specified temperature. After the test, the compressive force is removed, and the specimens are allowed to recover for 1 hour at the same temperature before the recovered width is measured. ASTM D 3542 requires 88 percent of low recovery in tests performed at 14 ± 2°F and 83 percent at –20 ± 2°F.

5.3.2 Compression-Deflection Properties

The purpose of the compression-deflection test is to determine the movement range of a compression seal. The results of the test are given in terms of Minimum Limit of Compressibility (LC min) and Maximum Limit of Compressibility

(LC max). Both the LC min and LC max are expressed as percentages of the nominal width. LC min is defined as the compressed width corresponding to a contact pressure of 3 psi. LC max is defined as the compressed width corresponding to a contact pressure of 35 psi.

Test specimens for the compression-deflection tests are prepared in the same way as those for the high- and low-recovery tests. The forces required to compress the specimen to LC min and LC max should be determined by multiplying the contact area by 3 psi and 35 psi, respectively. The forces should be applied to the specimens in accordance with Method A of ASTM D 575, Standard Test Methods for Rubber Properties in Compression, except that the rate of force application should be 0.50 ± 0.05 in./minute and the use of sandpaper specified in the document should be omitted. During the course of compression, the tendency of the top surface of the specimen to become horizontally misaligned should be observed. If misalignment exceeds 0.25 in., the seal should be rejected. The difference between LC min and LC max is the permissible range of movement for the specimen.

5.3.3 Tensile Strength

Tensile strength and elongation at break are two important parameters that can be used to predict whether seals will perform well in the field. The test method is explicitly detailed in ASTM D 412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension.

The test specimens should be formed in the shape of a standard dumbbell using Die C described in ASTM D 412 unless the flat sections of the seal are too small for Die C. In such a case, Die D may be used. A machine able to provide a uniform rate of grip separation of 20 ± 2 in. should be used in the test. The test should be run at a temperature of 73 ± 4°F, and the relative humidity should be maintained at 50 ± 5 percent throughout the test if the material is affected by moisture. The specimens should be placed under these conditions at least 24 hours before the test starts. For a compression seal to pass the requirements of

ASTM D 3542, it must exhibit a minimum tensile strength of 2,000 psi and a minimum elongation at break of 250 percent.

5.3.4 Durometer Hardness

Indentation hardness of sealants should be tested by a Type A durometer as specified in ASTM D 2240, Standard Test Method for Rubber Property—Durometer Hardness. The test specimens should be at least 0.25 in. thick. This thickness may be obtained by a composition of plied pieces. The surfaces of the specimen should be flat and parallel over a sufficient area so that the presser foot is allowed to have a minimum 0.5-in.-diameter contact area on the specimen. Also, the surfaces of the specimen should not be rounded, uneven, or rough. ASTM D 3542 requires that sealants exhibit 55 ± 5 points of hardness.

5.3.5 Oven Aging

The tensile and durometer hardness tests should also be conducted on specimens that are placed in an oven at 212°F for 70 hours. Preparation of specimens is exactly the same as mentioned in the sections given earlier for each test. After the specimens are heated for 70 hours, they are then tested for tensile strength and elongation at break in accordance with ASTM D 412 and tested for durometer hardness in accordance with ASTM 2240. In order to pass the tests, sealants must not lose more than 20 percent of their tensile strength or elongation at break and must not have an increase in hardness exceeding 10 points compared to the results from tests under normal conditions.

5.3.6 Oil Swell

The oil swell test is used to determine the ability of sealant materials to withstand the effect of liquids. The test method is detailed in ASTM D 471, Standard Test Method for Rubber Property—Effect of Liquids. Unless otherwise specified, the specimens should be prepared in accordance with the requirements of ASTM D 3182, Standard Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets, and

ASTM D 3183, Standard Practice for Rubber—Preparation of Pieces for Test Purposes from Products. The type of oil used in the test should be ASTM Oil No. 3. The test should be conducted at 212°F for 70 hours. ASTM D 3542 specifies that the sealant must not experience a weight increase greater than 45 percent.

5.3.7 Ozone Resistance

The ozone resistance test is used to estimate the resistance of sealant materials to cracking when exposed to an atmosphere containing ozone. The test method is explained in ASTM D 1149, Standard Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber. The specimens for the test should be prepared in accordance with Method A of ASTM D 518, Standard Test Method for Rubber Deterioration—Surface Cracking. The specimens should be cleaned with toluene to remove surface contamination prior to testing. The prepared specimens should then be subjected to a surface tensile strain of 20 percent in a chamber containing 300 parts per hundred million (pphm) in air at 104°F for 70 hours. ASTM D 3542 specifies that sealants should exhibit no cracks after the test. Specimens fail the test if cracking, splitting, or sticking occurs during either the high- or low- recovery tests described earlier.

5.4 STRIP SEALS

Specifications for strip seals are described in ASTM D 5973, Standard Specification for Elastomeric Strip Seals with Steel Locking Edge Rails Used in Expansion Joint Sealing. The use of structural steel locking edge rails should conform to ASTM A 588, Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4-in. [100-mm] Thick; ASTM A 36, Standard Specification for Carbon Structural Steel; ASTM A 572, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel; or other specifications given by the purchaser.

Many of the strip seal tests are the same as those mentioned in ASTM D 3542 for compression seals, although a couple of tests specified in ASTM D 5973 are not mentioned in ASTM D 3542. The tests that are excluded in ASTM

D 5973 are the high- and low-recovery tests and the compression-deflection test. Instead, a low-temperature stiffening test and a compression-set test are included in ASTM D 5973. The following sections provide brief explanations of the tests used to measure tensile strength, durometer hardness, oven aging, oil swell, ozone resistance, low-temperature stiffening, and compression set for strip seal materials. Details concerning specimen preparation are not given if the method is the same as one previously described for compression seals.

5.4.1 Tensile Strength

Tensile strength and elongation at break for strip seal materials should be tested in accordance with ASTM D 412. ASTM D 5973 requires that strip seal materials exhibit a minimum tensile strength of 2,000 psi and a minimum elongation at break of 250 percent.

5.4.2 Durometer Hardness

Indentation hardness of sealants should be tested by a Type A durometer as specified in ASTM D 2240. ASTM D 3542 requires that strip seal materials exhibit 55 to 65 points of hardness.

5.4.3 Oven Aging

As with compression seal materials, the tensile strength, elongation at break, and durometer hardness of strip seal materials should be measured after the materials have been conditioned in an oven at 212°F. After the specimens are heated for 70 hours, the specimens are then tested for tensile strength and elongation at break in accordance with ASTM D 412 and for durometer hardness in accordance with ASTM D 2240.

For a strip seal material to pass the tests, the material must not lose more than 20 percent of its tensile strength or elongation at break and must not have an increase in hardness exceeding 10 points compared to the results from tests under normal conditions.

5.4.4 Oil Swell

The oil swell test should be performed in accordance with ASTM D 471. The type of oil used in this test should be Industry Reference Materials 903, however, instead of ASTM Oil No. 3, which is specified for testing of compression seals. The test should be performed at 212°F for 70 hours. ASTM D 5973 requires that the weight increase of strip seal materials not exceed 45 percent.

5.4.5 Ozone Resistance

Strip seal materials should be tested for ozone resistance in accordance with ASTM D 1149. ASTM D 5973 requires that strip seal materials exhibit no cracks after the test. A specimen fails the test if cracking, splitting, or sticking occurs during either the high- or low- recovery tests described earlier.

5.4.6 Low-Temperature Stiffening

The low-temperature stiffening test is used to determine the change in hardness of strip seal materials after they are conditioned at 14°F for 7 days. The test should be performed in accordance with ASTM D 2240. ASTM D 5973 requires that strip seal materials not have an increase in hardness exceeding 15 points after low-temperature conditioning.

5.4.7 Compression Set

The compression set of strip seal materials should be evaluated according to Method B of ASTM D 395. The test specimens should be cylindrical disks cut from a laboratory-prepared slab. The standard dimensions of the specimens are 0.24 $\pm$ 0.01 in. in thickness and 0.51 $\pm$ 0.01 in. in diameter. All specimens should be conditioned at 73 $\pm$ 4°F for at least 3 hours prior to testing. If compression set has been shown through past experience to be affected by atmospheric moisture, the specimens should also be conditioned at a relative humidity of 50 $\pm$ 5 percent for at least 24 hours before the test is conducted.

After the specimens are conditioned for the specified duration of time, they should be compressed to constant deflection by using a compression clamp at 212°F for 70 hours before the compression set is calculated using Equation 5.2:

$$CS = \frac{t_0 - t_f}{t_0} \cdot 100 \tag{5.2}$$

where CS = compression set, %

t_0 = original thickness, in.

t_f = final thickness, in.

ASTM D 5973 requires that strip seal materials not exhibit compression set exceeding 35 percent.

5.5 ADHESIVE LUBRICANTS

Adhesive lubricants are necessary for installation of both compression seals and strip seals to ensure adequate bonding to the bridge deck. Adhesive lubricants for these applications should conform to ASTM D 4070, Standard Specification for Adhesive Lubricant for Installation of Preformed Elastomeric Bridge Compression Seals in Concrete Structures. ASTM D 4070 can generally be divided into two parts, general requirements and physical requirements.

The general requirements state that the adhesive lubricant shall be a single-component, moisture-curing, polyurethane compound extended with aromatic hydrocarbon solvent. The compound must provide adequate lubrication for insertion of the seal into the joint and, in the actual field application, must bond the seal to the joint face throughout repeated cycles of expansion and contraction, effectively sealing the joint against moisture ingress (*26*).

The second part of the specification describes a series of tests for evaluating the physical properties of the adhesive lubricants, including solids content, viscosity and shear ratio, lubricating life, sag, and peel strength. Specimens of the adhesive lubricant to be tested should each be 1 quart in volume and consist of a composite sampled from three or more separate containers chosen at random from the same batch. The following sections describe each test briefly.

5.5.1 Solids Content

The solids-content test is conducted by placing approximately 0.0035 lb of the adhesive lubricant uniformly over the bottom of an aluminum-foil drying dish using a rod. Then, the dish with the rod and contents are placed in a circulating-air oven at 221 ± 4°F for approximately 3 hours. Afterwards, the warm dish with the rod and lubricant sample are placed in a desiccator for cooling to room temperature before the solids content is calculated using Equation 5.3:

$$SC = \frac{w_r}{w_s} \cdot 100 \qquad (5.3)$$

where SC = solids content, %

w_r = weight of residue, lb

w_s = weight of specimen, lb

ASTM D 4070 requires that the solids content of the adhesive lubricant be at least 60 percent.

5.5.2 Viscosity and Shear Ratio

The Brookfield viscosity of the material is determined at 73 ± 4°F in accordance with Method B of ASTM D 1084, Standard Test Methods for Viscosity of Adhesives. ASTM D 4070 requires a viscosity of between 20,000 and 300,000 cP. The shear ratio of the material can be calculated by dividing the viscosity at 0.5 rpm by the viscosity at 2.5 rpm. For lubricant materials to meet the requirements, they must have minimum shear ratios of 1.5, 2.0, and 2.5 for viscosities in the range of 20,000 to 100,000 cP, 100,001 to 200,000 cP, and 200,001 to 300,000 cP, respectively. However, in any range of viscosity, the lubricant material must not have a shear ratio greater than 4.0.

5.5.3 Lubricating Life

In the lubricating-life test, a 2.5-in.- to 3.0-in.-wide by 6-in.-long by 0.030 ± 0.004-in.-thick strip of the adhesive lubricant is applied to a glass plate or smooth-surface paper test chart. The lubricating life of the adhesive lubricant is then tested by finger-rubbing the coated chart at 30-minute intervals. The time at which the drag or friction increases noticeably and the material starts to thicken or become tacky is recorded as the lubricating life of the lubricant. In order to pass the test, a lubricant must have at least 2 hours of lubricating life as specified in ASTM D 4070.

5.5.4 Sag

Specimens evaluated in the sagging test are prepared in the same manner as described in the lubricating-life test. After the lubricant specimen is applied to the glass plate or the smooth-surface paper test chart, it is supported vertically with the 6-in. side horizontal for 1 hour. The lubricant should be rejected if sagging occurs within the first hour of the test.

5.5.5 Peel Strength

The procedures of the peel strength test are detailed in ASTM D 4070. In the test, rubber strips, concrete blocks, a steel roller, steel blocks, and 1.1-lb and 2.2-lb weights are used. A 1-in.-wide rubber strip is roughened with a coarse grinding wheel. A brush coat of freshly mixed lubricant adhesive is then applied to the roughened surface of the rubber strip and to a concrete block surface. A 2-in. steel roller weighing 10 lb is then used to roll down the rubber strip after the coated surfaces are placed together. After six passes of rolling, a 2-in.-wide steel block weighing 10 lb is placed on the strip, and the specimen is cured for 48 hours. After curing, the steel block is removed, and about 1 in. of one end of the rubber strip is separated from the concrete. The concrete block is then rotated so that the rubber strip is still horizontal but facing downward. A 1.1-lb weight is then suspended from the free end of the rubber strip for 3 minutes. The distance the rubber strip peels away from the concrete is measured, and the weight is removed. The procedure is then repeated for a 2.2-lb weight. ASTM D 4070 requires the maximum lengths peeled from the concrete within 3 minutes to be 0.0 in. and 0.5 in. for 1.1-lb and 2.2-lb weights, respectively.

5.6 SUMMARY

To facilitate identification of adequate bridge deck joint products, testing of sample joint products should be performed. Test methods for poured seals, compression seals, and strip seals are published in the ASTM standards. However, research and laboratory testing have shown that certain test methods for poured seals need to be modified to improve the reliability of the resulting performance characterizations of sealants proposed for bridge deck applications.

Unlike tests for poured seals, research investigating the reliability of ASTM test methods for compression seals and strip seals has apparently not been conducted. Therefore, the test methods outlined in the ASTM standards should be used.

CHAPTER 6
DESIGN, INSTALLATION, AND MAINTENANCE OF JOINTS AND ANCHORAGES

6.1 PROCEDURAL RECOMMENDATIONS

A well-sealed joint requires accurate design, proper installation, and regular maintenance. Researchers have affirmed that, while the sealing products may have room for improvement, the solution to the problem of obtaining well-sealed joints is not simply to require improvement of the products (*27*). In this chapter, suggestions on design, installation, and maintenance given by numerous transportation agencies are provided for several joint types, including finger joints, poured seals, asphalt plug joints, compression seals, strips seals, and reinforced elastomeric joints. Suggestions generally applicable to all joint types are also summarized.

While the integrity of the bridge deck joint itself contributes to its success, the quality of the anchorage systems is equally important. For example, researchers at the Pennsylvania DOT observed in their studies that numerous installations were listed as failures because the anchorages had failed (*4*). For this reason, a summary of general anchorage design and installation procedures recommended by several transportation agencies is also given in this chapter.

6.2 FINGER JOINTS

The design, installation, and maintenance of finger joints are discussed in the following sections.

6.2.1 Design

1. For traffic safety considerations, the following requirements should be followed (*28*):
    a. The minimum joint opening in the longitudinal direction should be limited to 1 in.

   b. At the maximum joint opening, teeth should overlap at least 2 in.
   c. Floor plates should be used in the shoulder and sidewalk areas when bicycle use is anticipated.
2. Finger plates cannot account for differential deflection, rotation, or settlement across the joint; if these types of movements are expected, finger joints should not be used (*28*).
3. Finger plates should have adequate stiffness to avoid excessive vibration (*28*).
4. Finger plates should have sufficient tensile strength to avoid bending (*4*).
5. Anchorages should be designed with sufficient tensile strength to handle loads from heavy traffic and snowplows (*4*).
6. The slope of the trough should be at least 8 percent to prevent debris accumulation (*4, 28*).
7. Corrosion protection should be used on steel troughs. Steel surfaces should be repainted periodically (*1*).
8. When elastomeric troughs are specified, low-durometer elastomeric materials should be used to help prevent tearing (*1*).
9. Stainless steel bolts, nuts, and washers should be used (*1*).

6.2.2 Installation

1. Cantilever fingers should be aligned properly (*4*).
2. The top of the steel fingers should be placed between 0.125 in. and 0.156 in. (5/32 in.) below the roadway surface; the fingers should be tapered slightly downward to prevent snowplow damage (*28*).
3. Concrete edges along the joint should be chamfered (*28*).
4. Finger plates should not be covered by paving concrete (*4*).

6.2.3 Maintenance

1. Troughs should be cleaned at least once a year or more often if needed (*28*).

2. The joint must be kept free of corrosion, and damaged fingers must be repaired (*29*).

6.3 POURED SEALS

The design, installation, and maintenance of poured seals are discussed in the following sections.

6.3.1 Design

1. Sealants should have a shape factor between 1.0 and 1.5 to ensure an adequate bond area and strain capacity. Sealant thickness should not be less than 0.5 in. (*1, 30, 31*).
2. The American Concrete Institute suggests that a sealant should have the following properties (*1*):
    a. Be impermeable.
    b. Deform to accommodate the design magnitude and rate of movement.
    c. Have the ability to retain its original shape.
    d. Adhere to concrete.
    e. Not internally rupture or fail in cohesion.
    f. Resist flow due to gravity.
    g. Resist unacceptable softening at high service temperatures.
    h. Not harden or become unacceptably brittle at low service temperatures.
    i. Not contain substances that are harmful to users or concrete.
3. Backer rods should be soft and flexible, not adhere to or react with the sealant, and not absorb water (*6, 31*).
4. Backer rods must be compressible so that they will not expel the sealant when the decks expand (*1*).
5. Backer rods should be at least 25 percent greater in width than the maximum joint opening to ensure constant compressive pressure on the concrete surface through time (*6*).

6. Backer rods must recover to maintain contact with the joint faces when the joint is open (*1*).
7. Extra caution should be used in choosing a sealant intended to adhere to steel-armored joints. In general, sealants adhere better to a concrete substrate than to a steel substrate (*32*).
8. Selection of sealants should be based on the specified strain capacity of the sealant material and the predicted allowable joint openings and movements (*1*).
9. Sealants with adequate strain capacity at low temperatures should be selected (*7*).

6.3.2 Installation

1. Manufacturers' installation specifications should always be followed (*7*).
2. Joint sawing, if required, should be performed to the specified depth and width and at the proper time. Early sawing can result in edge spalling and plucked aggregate, but late sawing can cause random cracks to occur (*1*).
3. Curing compounds should not be allowed to contaminate the joint faces (*1*).
4. Concrete should be sand-blasted so that the prepared surface is free of all original adhesives or sealants, tar and asphalt, discoloration and stain, and any other contamination, leaving a clean, newly exposed concrete surface (*6*).
5. Blasting sand should be removed from the vicinity of the joint prior to installation of the sealant (*6*).
6. Sealants should never be applied to a joint that is damp or wet (*1, 30*).
7. Sealants should have a minimum installation width of 0.25 in. Maximum installation widths vary with the type of sealant used. Mastics, thermoplastics, and solvent-release thermosetting sealants can be used in joint openings up to 1.5 in. with allowable movements of 0.25 in. Chemically-curing thermosetting sealants can be used in joint openings up to 4 in. wide and accommodate up to 2-in. movements (*1*).

8. Two-component sealants should be mixed thoroughly. Once mixed, two-component sealants have a limited working (pot) life and typically cure faster on hot days (*1*).
9. Joint width and temperature should be checked against joint design assumptions. Joint sealant compounds should not be installed if the bridge deck joint temperature is below 40°F or above 90°F (*1*).
10. A sealant should be tooled after it is placed in the joint to ensure that it is set to the proper depth, all voids are removed, and it is adequately pressed against the joint walls (*30*).
11. If priming is needed, sealants should not be installed before the primers are dry (*1*).
12. Backer rods must be set at the correct depth, must be installed without twisting, and must not contaminate the cleaned joint faces (*1*).

6.3.3 Maintenance

1. To obtain maximum sealant performance, sealants should be repaired in the spring or fall to reduce the strain imposed on the seal (*33*).

6.4 ASPHALT PLUG JOINTS

The design, installation, and maintenance of asphalt plug joints are discussed in the following sections.

6.4.1 Design

1. Joints for roads with significant cross-sectional or profile gradients should be designed using relatively stiff binders to reduce debonding and binder flow (*9*).
2. Joints should be linear with uniform widths of at least 20 in. (*9*).
3. Localized widening should be avoided, especially on heavily trafficked roads (*9*).
4. If widening is unavoidable, stiffer binders should be used to minimize deformation and binder flow (*9*).

6.4.2 Installation

1. Before the joint is installed, all loose material should be removed from the deck, and the deck substrate should be thoroughly dry (*9*).
2. Bridging plates should be installed across the expansion gap to prevent extrusion of the joint material into the gap under traffic loads (*9*).
3. Joints should be continued straight through the curb. The depth of the curb over the joint should be reduced to ensure that the full joint depth can be maintained under the curb (*9*).
4. The joint and transition strips should be approximately level with the adjacent deck surfaces to provide good ride quality (*9*).

6.4.3 Maintenance

1. If the surfacing adjacent to a failed joint deteriorates, both the joint and the deteriorated surfacing should be replaced to improve ride quality and overall durability (*9*).

6.5 COMPRESSION SEALS

The design, installation, and maintenance of compression seals are discussed in the following sections.

6.5.1 Design

1. Armor steel should be used to protect the joint and the surrounding concrete on bridges subject to high traffic volume, heavy truck traffic, and snowplows (*3*).
2. A compression seal should be sized in a working range of 40 percent to 85 percent of its uncompressed width to ensure that positive contact pressure is exerted against the joint faces at all times (*1, 10, 28*).
3. Compression seals should not be used on skewed joints angled more than 45 degrees, measured from the transverse direction (*28*).

4. The seal should be continuous across the bridge deck and reach high enough into the parapet sections to prevent accumulated snow from leaking over the top of the joint (*21*).
5. Proper tools should be used during installation; otherwise, seals may be vulnerable to damage (*29*).

6.5.2 Installation

1. Compression seals should be set below the joint so they do not protrude above the roadway surface when the seal is fully compressed (*3*).
2. An installing machine such as the Delastall Auto-Installer, for example, should be used to set the seal at a uniform depth without causing excessive longitudinal stretching (*10*).
3. Armor plates should be coated with epoxy in the shop during the manufacturing process (*4*).

6.5.3 Maintenance

1. Armor should be repainted periodically or coated with epoxy in the shop during manufacturing (*4*).

6.6 STRIP SEALS

The design, installation, and maintenance of strip seals are discussed in the following sections.

6.6.1 Design

1. The recommended maximum width is 4 in. A 4-in. maximum width will reduce traffic impacts on the joint, improve the ride, and reduce the hazard to motorcycles (*28*).
2. Strip seals should not be used on bridges with skews greater than 30 degrees (*28*).
3. Joints should not be field-spliced. Continuous seals should be used if possible (*34*).

4. Split-steel extrusions should be used for curb installations, and traffic barriers and sliding steel plates should be used for sidewalk installations to protect the seals from damage (*28*).
5. Bolted anchorage systems should not be used (*28*).
6. Anchorages should be designed to resist the expected impact loads, not merely the static loads (*28*).
7. Fasteners with conical-shaped heads should be used to hold down the retainer plates to prevent slippage between the retainer plates and the fasteners (*34*).
8. Strip seals should not be dependent on bonding agents to hold them in place (*34*).

6.6.2 Installation

1. Strip seals usually have a 1.5-in. minimum required installation width normal to the joint (*28*).
2. Proper bonding of the anchorage to the concrete should be ensured. Concrete should be thoroughly consolidated in order to remove entrapped air voids. Ventholes should be added to the armor to allow the air to escape (*3, 9*).
3. Field splices should not be used (*34*)
4. A continuous seal should be inserted across the complete bridge deck from parapet to parapet to improve the watertightness of the joint (*9*).

6.6.3 Maintenance

1. Concrete overlays should not be placed over the anchorage system (*9*).
2. If partial repairs are necessary, seals should be patched using a new piece of seal (*35*).

6.7 REINFORCED ELASTOMERIC JOINTS

The design, installation, and maintenance of reinforced elastomeric joints are discussed in the following sections.

6.7.1 Design

1. Tensioned, cast-in-place bolts should be used when possible (*9*).
2. Cast-in-place or epoxy-resin anchors should be used to reduce anchorage failure (*36*).
3. Continuous seals should be used when possible (*29*).
4. When the use of a segmental seal is unavoidable, a continuous sheet trough should be placed underneath the seal along the entire length of the joint to prevent water from damaging the structure. Adequate depth and slope for the trough should be ensured (*36*).
5. For concrete replacement around a joint, temperature reinforcing steel should be used to minimize cracking in the concrete (*9*).

6.7.2 Installation

1. Seals should be placed 0.125 in. to 0.156 in. (5/32 in.) below the adjacent deck surfaces to reduce impact loads from traffic and snowplows (*9*).
2. Segmental panels should be jacked together to limit leaking between the segments (*36*).
3. Any steel reinforcing plates that have sharp edges should be removed to prevent seal tearing (*9*).
4. An adhesive sealant should be applied on butt joints between segments (*9*).
5. Concrete edges adjacent to the joint should be chamfered to reduce wheel impact loads (*9*).

6.7.3 Maintenance

1. The bolts should be re-torqued after at least 7 days following initial installation to compensate for the creep of the elastomer, and all bolts should be re-tightened annually (*37*).
2. Any damaged sections on segmental seals should be replaced (*37*).
3. All lost bolt plugs should be replaced (*37*).

6.8 GENERAL RECOMMENDATIONS FOR JOINTS

The following section gives suggestions generally applicable to the design, installation, and maintenance of all types of joints.

6.8.1 Design

1. Joint details should be described and shown on the work plan (*31*).
2. Drains should be placed uphill of the joint in the sidewalk or curb to prevent as much water as possible from reaching the joint. (*9*)
3. The use of aluminum components is not recommended, as they are easily damaged (*19*).
4. Steel devices must be protected with a coating such as paint or galvanization (*35*).
5. Joints should be designed for movements that are likely to occur (*3*).
6. Deck joints with little or no tolerance for unanticipated foundation movements should not be used (*3*).
7. Joints sensitive to skews should not be used in bridges with large skews (*3*).
8. Sliding plate joints should not be used where vertical movements and rotations are probable (*3*).
9. Only joints that have been subjected to successful load tests should be used on highway bridges (*3*).
10. Bridging-type joints should only be used if they can survive the application of substantial vehicular overloads (*3*).
11. Wide elastomeric joints should not be used in snowplow environments (*3*).

12. Joints with expansion anchor bolts exposed at the roadway surface should not be used (*3*).
13. Substantial joint edge armor and armor anchorage should be used on all joints (*3*).

6.8.2 Installation

1. Adequate time should be made available to the contractor to complete the installation without rushing and without opening the road to traffic prematurely (*9*).
2. Inspection should be enforced at all times during installation (*31*).
3. Joints and joint armor should be placed between 0.125 in. and 0.156 in. (5/32 in.) below the deck surface to eliminate exposure to snowplow impacts (*3, 37*).
4. Ventholes or bleeder holes should be placed in joint-edge armor to enable expulsion of entrapped air during concrete placement (*3*).
5. Concrete under the armor should be consolidated properly to ensure elimination of voids (*3*).
6. Concrete buffer strips should be used adjacent to joint edge armor to minimize rutting (*3*).
7. Armor anchor bars should be properly positioned to resist snowplow impacts (*3*).
8. The armor anchors should be of sufficient length to prevent pull-out (*3*).
9. The joint armor should be of sufficient width to allow proper attachment of the anchorage (*3*).
10. Continuous seals should be used (*3*).
11. A concrete saw should be used to cut the joint opening for unarmored compression seals to ensure a constant joint width (*3*).
12. Armors that are thick enough to avoid welding distortion should be used (*3*).

6.8.3 Maintenance

1. A failed joint should be entirely replaced since completely sealing the interface between existing and new joint faces is very difficult (*9*).
2. Areas in the approach slab and deck that exhibit excessive vehicle wear should be repaired immediately to reduce impact loads on the joint (*37*).
3. A regular maintenance program should be established, including cleaning of drains and removal of debris from around the joints (*9*).

6.9 GENERAL RECOMMENDATIONS FOR ANCHORAGE SYSTEMS

The following section provides recommendations applicable to the design and installation of anchorage systems in general.

6.9.1 Design

1. Cast-in-place anchors should be used to increase resistance to pull-out (*37*).
2. Anchorages should be placed in materials with strength similar to that of the structural concrete, but preferably with greater ductility and energy absorption. Elastomeric concrete, fiberglass-reinforced concrete, and slurry-infiltrated concrete have sufficient strength and ductility to be classified as shock-absorbing embedment materials. While the use of fiberglass-reinforced concrete and slurry-infiltrated fiber concrete is still in experimental stages, elastomeric concrete has already been proven to be reliable in the field (*37*).

6.9.2 Installation

1. Proper consolidation of the concrete surrounding the armor is critical. Placing ventholes in the top of the armor aids in the removal of entrapped air from beneath the armor (*19*).

6.10 SUMMARY

The performance of bridge deck joints does not depend strictly on the quality of the joint materials. Performance is also heavily dependent on the design skills of the bridge engineer, the use of specialty contractors for proper installation, and the establishment of a maintenance program. In addition, joint performance also depends on the quality of the support available from the anchorage system, which should also be designed appropriately, installed properly, and maintained regularly. The suggestions given in this chapter on design, installation, and maintenance of bridge deck joints and their anchorage systems are based on experience and research. If the suggestions are strictly followed, the service lives of bridge deck joints should be maximized.

CHAPTER 7
QUESTIONNAIRE SURVEY RESULTS

7.1 SURVEY PURPOSE

As the culminating element of this research, a questionnaire survey was conducted to determine the current practices of state DOTs concerning concrete bridge deck joints. The survey was directed primarily at identifying practices utilized by state DOTs in climates with freezing temperatures. Thirty-eight state DOTs were selected for the survey, and individuals most capable of describing the state-of-the-practice concerning bridge deck joints were identified through telephone calls to each state DOT office. The survey was then e-mailed to each state for completion by the appropriate individual. Responses were received from the following 20 states: Delaware, Idaho, Illinois, Kansas, Michigan, Missouri, Nevada, New Jersey, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Carolina, South Dakota, Utah, Vermont, Wisconsin, and Wyoming. The survey consisted of five questions soliciting information concerning the respondent, such as name, title, and contact information. The final seven questions asked for information concerning concrete bridge deck joints. The survey responses are summarized in the following sections.

7.2 PARTICIPANT INFORMATION

The majority of the respondents were state bridge engineers or bridge maintenance specialists. Since participant information was collected to facilitate follow-up questioning as needed, specific information concerning each participant is not included in this report. The following questions were asked in regards to the participant:

Question 1. What is your name?

Question 2. What is your job title?

Question 3. For which department of transportation do you work?

Question 4. What is your phone number?

Question 5. What is your e-mail address?

7.3 SURVEY RESULTS

The survey included seven questions regarding concrete bridge deck joints. This section provides a brief summary of the responses.

Question 6. What is the typical range of movement you design concrete bridge deck joints to accommodate?

The participants responded with a wide range of values. Some gave specific measurements, while others gave detailed paragraphs describing the types of joints they use for various expansion movements. Quantitative responses are listed in Table 7.1 and compiled in Figure 7.1 to facilitate comparison of the responses. The most common deck joint movements are in the range of 1 in. to 4 in. The responses that were not a simple numerical expression are summarized in the following paragraph.

The Illinois DOT uses modular joints for expansions exceeding 8 in. The participant from the Nevada DOT stated that he used whatever is required by the design but a minimum of 1 in. The North Dakota DOT respondent stated that the majority of bridges constructed in the past 25 years are jointless, integral abutment bridges. According to the Ohio DOT response, most of the multi-span bridges in Ohio are also continuous. Finally, the Wyoming DOT respondent stated that compressed joint material is used for up to 1 in. of movement, compression seals are used up to 1.5 in. of movement, and strip seal expansion devices are used for greater movements.

TABLE 7.1 Expansion Movement Ranges

State	Expansion (in.)
Delaware	1
Idaho	2 to 5
Kansas	2 to 12
Michigan	2 to 4
Missouri	2
New Jersey	0 to 4
New Mexico	0.5 to 2.5
New York	1 to 2.5
Pennsylvania	2 to 12
South Dakota	0 to 4
Utah	1 to 6
Vermont	2
Wisconsin	0 to 12

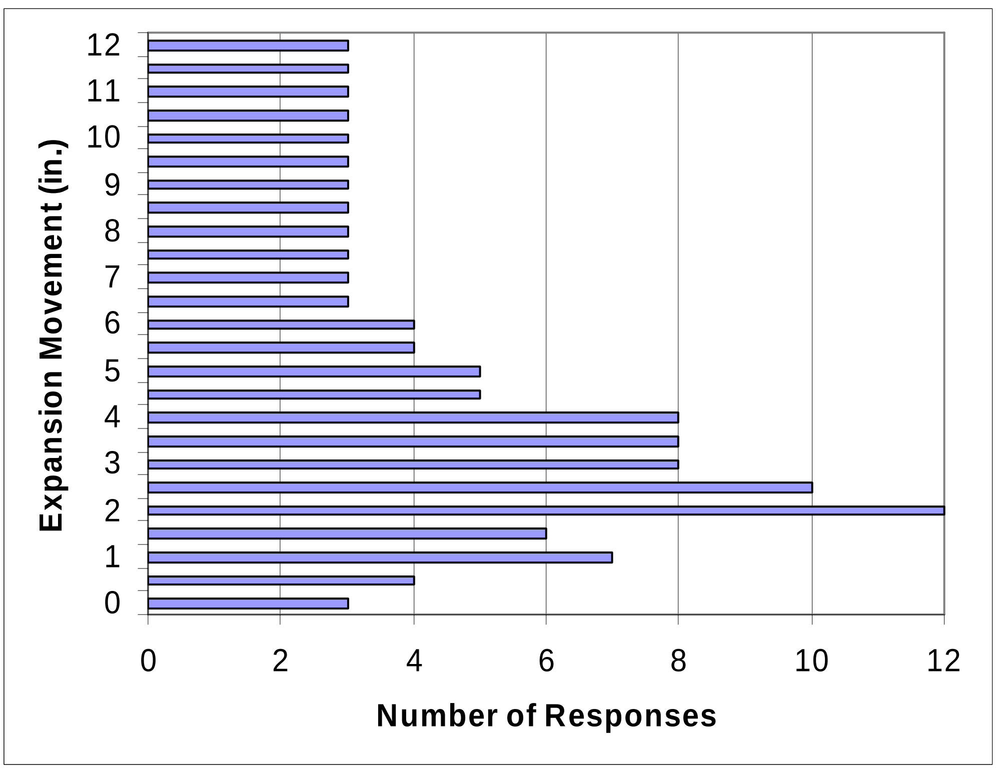

FIGURE 7.1 Expansion movement.

Question 7. What types of concrete bridge deck joints do you typically use?

Figure 7.2 shows the number of responses corresponding to each type of deck joint. Analysis of the survey responses shows that strip seal joints are the most accepted type of joints among the participating DOTs; of the 20 state DOTs that participated, only the Idaho DOT does not report commonly using strip seal joints. Finger joints and modular joints, respectively, are the second and third most commonly used joint types. These data seem consistent with the deck joint performance evaluations presented in Chapter 3.

Only the Ohio DOT cited the use of butt joints, which are used according to the AS-1-81 standard drawing. The Missouri, New Mexico, Ohio, South Dakota, and Wisconsin DOTs specified the use of sliding plate joints, but only the Missouri DOT and South Dakota DOT respondents suggested that these joints are still being installed on new bridges. The belief among both of these DOTs is that sliding plate joints last around 30 years; however, they disagree on the range of movement for which these joints should be used. The Missouri DOT uses them for 2 in. to 4 in. of movement, while the South Dakota DOT uses them for movements exceeding 4 in. The Missouri DOT reports that the cost of sliding plate joints is $400 per linear foot, while the South Dakota DOT cites a cost of $25,000 each.

Only the Idaho, Michigan, Nevada, New Mexico, and Utah DOTs do not typically use finger joints. Table 7.2 lists the DOTs that use finger joints together with design movement range, reported cost, and expected service life. Similarly, Tables 7.3 to 7.8 present the same data for field-poured seal, asphalt plug, compression seal, strip seal, reinforced elastomeric, and modular seal joints. Regarding field-poured seals, the New Mexico DOT has discontinued their use, whereas the New York DOT is increasing their use. The New Mexico DOT also has a history of failures with asphalt plug joints. Regarding strip seals, the Michigan DOT is more likely to replace the concrete surrounding the joint than the strip seal itself; however, the Ohio DOT respondent indicated maintenance and replacement problems with the strip seal materials themselves.

Only four states, including Delaware, New Mexico, New York, and Ohio, use joints that fell into the “other” category. The Delaware DOT uses Seal Mate and Will-Seal, which both reportedly cost about $35 per linear foot and last 5 to 15 years, although early failures have apparently caused the Delaware DOT to reconsider the use of these joints. The New Mexico DOT uses an Evazote product, which has been used as a replacement for field-poured joints for 2 years and has demonstrated satisfactory performance thus far; the Evazote joint is used for movements between 0.5 in. and 2.0 in. The New York DOT uses an epoxy-engineered material from Watson Bowman for expansions from 1 in. to 4 in.; that product has performed well for the 6 years it has been specified, and its use is now rapidly increasing.

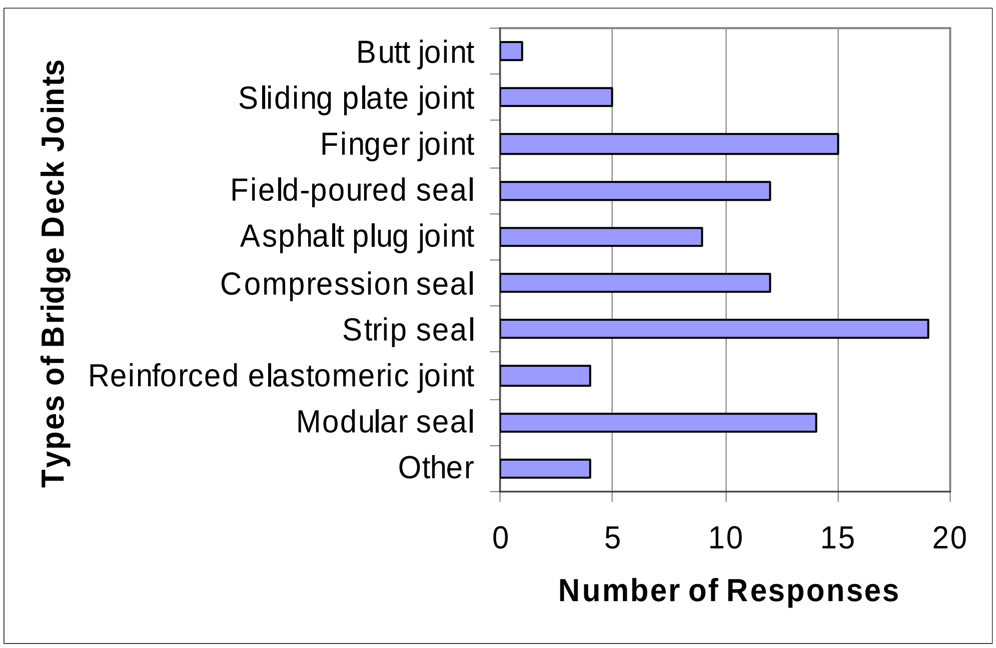

FIGURE 7.2 Types of bridge deck joints.

TABLE 7.2 Finger Joint Specifications

State	Movement Range (in.)	Cost	Service Life
Delaware	Greater than 3	-	-
Illinois	Up to 8	-	Long for steel components
Kansas	6 to 12	-	Good
Missouri	4 to 8	$900 per linear foot	30 years
New Jersey	Up to 4	-	-
New York	Large	Depends on design	Good
North Dakota	4 to 12	$700 to $1,100 per linear foot	30 years
Ohio	-	-	-
Pennsylvania	Greater than 4	-	-
Rhode Island	Greater than or equal to 6	$400 per linear foot	15 to 20 years
South Carolina	-	-	-
South Dakota	Greater than 4	$25,000 each	30 to 40 years
Vermont	Greater than 3	-	-
Wisconsin	-	-	-
Wyoming	Greater than 4	-	Over 40 years

TABLE 7.3 Poured Seal Specifications

State	Movement Range (in.)	Cost	Service Life
Delaware	Less than 0.5	$10 per linear foot	5 years
Idaho	Less than 2	-	-
Illinois	Up to 2.5	-	-
Kansas	1 to 2	-	-
Michigan	Less than 1	-	5 to 10 years
New Mexico	0.5 to 1	-	-
New York	Up to 1.5	$130 per linear foot	Greater than 8 years
Ohio	-	-	-
South Carolina	-	-	-
Utah	0.5 to 1	-	1 year
Vermont	0	-	-
Wisconsin	-	$500 to $1000	-

TABLE 7.4 Asphalt Plug Joint Specifications

State	Movement Range (in.)	Cost	Service Life
Delaware	No movement	-	-
Idaho	Less than 2	-	-
Nevada	Up to 1.5	$150 per linear foot	10 years
New Mexico	-	-	-
Ohio	-	-	-
Pennsylvania	Less than 1	-	-
Rhode Island	6 to 30	$100 per linear foot	5 to 15 years
South Dakota	0 to 2	$125 per linear foot	15 to 20 years
Vermont	Less than or equal to 2	-	-

TABLE 7.5 Compression Seal Specifications

State	Movement Range (in.)	Cost	Service Life
Delaware	Up to 0.5	$45 per linear foot	10 years
Illinois	Up to 1.625	-	-
Missouri	1 to 2	$300 per linear foot	15 years
Nevada	Up to 3	$100 per linear foot	10 to 15 years
New Jersey	Up to 4	$525 per linear foot	-
New Mexico	-	-	-
New York	Up to 3	$650 per linear foot	-
Ohio	-	-	-
South Carolina	-	-	-
South Dakota	0 to 1.5	$75 per linear foot	20 to 30 years
Wisconsin	-	-	-
Wyoming	Up to 1.5	-	15 years

TABLE 7.6 Strip Seal Specifications

State	Movement Range (in.)	Cost	Service Life
Delaware	1	$300 per linear foot	10 years
Illinois	Up to 1.625	-	-
Kansas	2 to 4	-	10 to 20 years
Michigan	Up to 4	-	Greater than 20 years
Missouri	1 to 3	$350 per linear foot	20 years
Nevada	Up to 5	$125 per linear foot	20 years
New Jersey	Up to 4	$1,600 per linear foot	-
New Mexico	0.5 to 2	-	20 to 40 years
New York	2.5	$203 per linear foot	10 years
North Dakota	Less than 4	$90 to $130 per linear foot	30 years
Ohio	-	-	-
Pennsylvania	Up to 4	-	-
Rhode Island	2 to 4	$250 per linear foot	15 years
South Carolina	-	-	-
South Dakota	Up to 4	$65 per linear foot	20 to 30 years
Utah	Up to 4	$500 per linear foot	15 years
Vermont	Less than or equal to 3	-	-
Wisconsin	Up to 5	-	Up to 20 years
Wyoming	1.5 to 4.5	-	15 years

TABLE 7.7 Reinforced Elastomeric Joint Specifications

State	Movement Range (in.)	Cost	Service Life
Illinois	Up to 4	-	-
Ohio	-	-	-
New Jersey	Up to 4	$1,400 per linear foot	-
Rhode Island	2.5 to 5	$300 per linear foot	10 to 20 years

TABLE 7.8 Modular Elastomeric Joint Specifications

State	Movement Range (in.)	Cost	Service Life
Idaho	Greater than or equal to 6	-	-
Illinois	Greater than 8	-	-
Michigan	Greater than or equal to 5	-	20 years
Missouri	10	$2,500 per linear foot	20 years
Nevada	Greater than or equal to 5	$1,250 per linear foot	Greater than 25 years
New Jersey	Greater than 4	$5,600 per linear foot	-
New Mexico	3 to 6	-	-
New York	Up to 13	Depends on number of cells	-
Ohio	-	-	-
Rhode Island	6 to 30	$400 per linear foot	15 to 20 years
South Carolina	-	-	-
Utah	Greater than 4	-	20 years
Wisconsin	Up to 12	Expensive	-
Wyoming	Greater than 5	-	-

Question 8. What specifications do you use for construction of new decks or rehabilitation of aged decks to ensure good joint performance?

Figure 7.3 shows the number of responses associated with each option available for this multiple-choice question. All comments regarding substrate preparation focused on the need for sand-blasting, reaching sound material, and applying adhesives and lubricants if needed. UDOT specifies the use of custom joint anchorages as part of the required substrate preparation. As far as equipment for construction, the Nevada DOT limits the size of jack-hammers permitted for removal of existing concrete, while the Wisconsin DOT allows the use of Morrison screeds.

Interesting comments concerning climatic factors were received from the Illinois, Michigan, and Missouri DOTs. The Illinois and Missouri DOTs require minimum ambient temperatures of 41°F and 40°F, respectively, in order for sealants to be poured or placed. The Michigan DOT uses a temperature correction table that states the target joint dimensions for given temperatures. Concerning lane closure requirements, UDOT prohibits traffic near the headers of newly constructed joints for 7 days after placement. The only comments about personnel expertise were that state employees inspected the work.

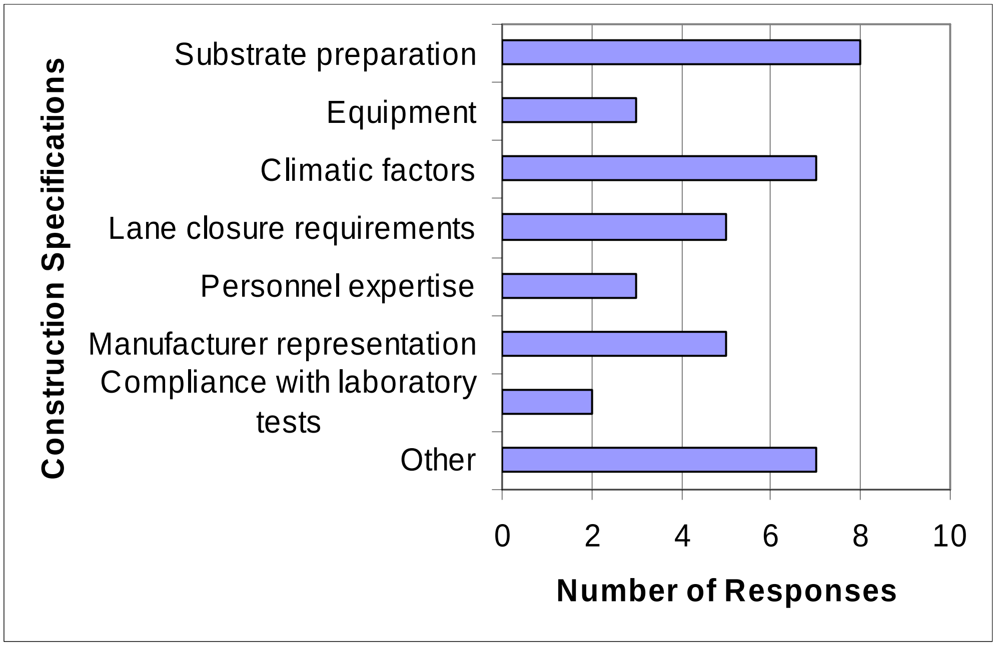

FIGURE 7.3 Construction specifications.

Respondents from the Illinois, Nevada, New York, and Wyoming DOTs commented with regards to manufacturer representation. The Illinois DOT requires a technical representative for at least 1 day during the surface preparation and sealant placement for poured seals. The Nevada DOT requires manufacturer representatives for modular joint installations. The New York DOT requires a manufacturer representative to be present during joint placements and for three days of continuous work for repetitive tasks. Lastly, the Wyoming DOT requires a representative for preparation and installation of joints. The participants from the South Dakota and Utah DOTs both commented that the materials had to meet certain laboratory test specifications.

Three state DOTs provided interesting comments under the “other” category. The Nevada DOT respondent stated that for new construction, expansion joints are blocked out and completed only after deck and approach slabs are complete. In New York, all joint construction is separated from general deck construction. The Ohio DOT prefers to use jointless bridges for all new construction and deck replacements.

Question 9. What are the most common modes of failure for the deck joints you use?

Figure 7.4 presents a summary of the responses received for this question. The New Mexico DOT respondent commented that field-poured seals constantly tear and debond. Other participants specifically stated that neoprene joints tear due to debris accumulation. The survey results suggest that seal separations are most commonly associated with field-poured joints and joints in which the seals are bonded to weathering steel.

According to several DOTs, compression seal and reinforced elastomeric joints are more likely to sustain snowplow damage than other types of joints. As indicated in Chapter 3, reinforced elastomeric joints are apparently especially vulnerable to snowplow damage. Most of the survey comments concerning snowplow damage indicated problems with armor angles.

A few states gave information about how to prevent snowplow damage. For example, the Michigan DOT has had few problems if the joint is recessed between 0.125 in. and 0.250 in., which is consistent with recommendations given in Chapter 6 of this report. Furthermore, according to the Wyoming DOT, snowplow protection plates can be installed across strip seals to prevent damage.

Both the Rhode Island and Illinois DOTs commented that spalling is common with elastomeric joints, while the Wyoming DOT reported spalling problems with compression seals. The New Jersey DOT reported that spalling occurs on older bridges without armor, whereas the New York DOT commonly observes spalling just behind the armor angles, which allows water to seep under the angle.

According to the survey responses, detachment of armor plates is generally caused by poor concrete consolidation or other inadequate construction practices and snowplow impacts. The Pennsylvania DOT claims that development of new anchorage specifications has solved the issue of armor detachment; however, debris accumulation, especially at the curb line, is a

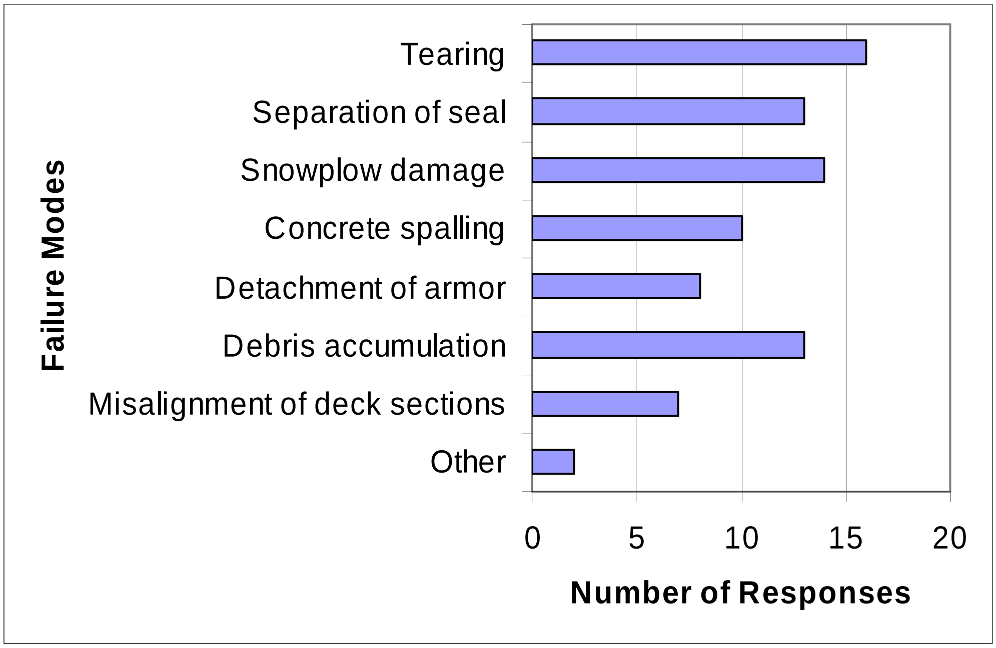

FIGURE 7.4 Common modes of joint failure.

common observation with all types of joints. The Michigan and Pennsylvania DOTs remarked that bridge decks within their jurisdictions are cleaned as part of regular bridge maintenance. The Michigan DOT respondent noted, for example, that the joints are cleaned every 3 to 5 years in that state.

Few survey participants commented on horizontal and/or vertical misalignment between adjacent deck sections. Where problems do occur, they are generally blamed on poor construction. The New York DOT respondent commented that pack rust causes vertical misalignment and subsequent snowplow damage. In the "other" category, the Illinois DOT cited heaving of compression seals that caused joint damage from traffic and snowplows, and the New York DOT commented that unanticipated temperature fluctuations were another cause of joint damage.

Question 10. Do you typically replace one type or brand of concrete bridge deck joint with another type or brand during rehabilitation? If yes, please provide details.

Eleven of the participants responded “yes” to this question, including the Delaware, Illinois, Michigan, New Mexico, New York, Ohio, Pennsylvania, South Dakota, Utah, Wisconsin, and Wyoming DOTs. A majority of these state DOTs reported that they upgrade from compression seals and sliding plates to strip seals. The New Mexico DOT reported “constantly replacing compression seals with strip seals.” The South Dakota DOT attempts to make their decks continuous and therefore eliminate the use of joints; however, when this is impossible, they primarily use strip seals. The New York DOT replaces armor-angle joint types with “maintenance-friendly” systems, meaning that they can be easily repaired. Such products typically include elastomeric concrete headers with poured or preformed joint material. The New York DOT respondent also noted that armor angles and strip seals are difficult to repair.

Question 11. Do you specifically avoid using certain types or brands of concrete bridge deck joints? If yes, please provide details.

Eleven participants responded “yes” to this question, including the Kansas, Michigan, New Jersey, New Mexico, New York, Ohio, Rhode Island, South Dakota, Utah, Wisconsin, and Wyoming DOTs. The Rhode Island, Utah, and Wisconsin DOTs stated that they avoid the use of compression joints, while the Kansas and South Dakota DOTs stated that they avoid the use of modular joints. The Michigan DOT only allows the use of certain approved joints. The New Jersey DOT avoids bolt-down joint armoring in new or replacement construction. The New Mexico and Wisconsin DOTs both mentioned that strip seals are the preferred joints in their respective states. The New York DOT generally avoids the use of plug joints, due to their short service life, and Jenne joints, because of their poor performance record. The Ohio DOT prohibits the use of early SD 1-69 and unsealed joints, while the Rhode Island DOT avoids the use of sliding plates because the plates easily sustain snowplow and impact damage. UDOT does not allow the use of compression seals, finger joints, or sliding plates, while the Wisconsin DOT does not allow the use of elastomeric expansion joints.

Question 12. Do you conduct periodic inspection and maintenance of concrete bridge deck joints? If yes, please provide details regarding the type of data you collect, inspection, frequency, and maintenance actions.

Thirteen states responded “yes” to this question, including the Delaware, Illinois, Kansas, Michigan, Nevada, New Jersey, New Mexico, New York, Ohio, Rhode Island, South Carolina, South Dakota, and Utah DOTs. The Delaware, Kansas, Illinois, New Mexico, New York, and South Dakota DOTs explained that their only routine inspections are associated with National Bridge Inventory (NBI) reporting requirements. Also following NBI procedures, the Michigan DOT inspects each bridge every 2 years and includes the joint opening and field temperature in the records with a description of the general bridge condition. The Ohio DOT inspects bridges every 1 to 2 years; during each inspection, the bridge is cleaned, and the joints are checked to make sure that they are free of debris. The Rhode Island DOT conducts inspections every 1 to 2 years; during these inspections, temporary asphalt and concrete patching takes place. The South Carolina DOT inspects its bridges on a yearly basis; at the time of the inspection, debris is cleaned from the joints, and data are collected on the joint opening, temperature, and general deck condition.

7.4 SUMMARY

As the final task of this research, a questionnaire survey was conducted to determine the current practices of state DOTs concerning concrete bridge deck joints. Responses were received from 20 of the 38 states invited to participate in the survey, corresponding to a 53 percent response rate. Analyses of the survey data indicate that the most common deck joint expansion movements are in the range of 1 in. to 4 in. and that strip seal joints are the most commonly specified joint type among the participating DOTs. In fact, a majority of the respondents reported that they generally upgrade deteriorated compression seals and sliding plates to strip seals. The survey respondents placed special emphasis on the importance of proper substrate preparation and adequate anchorage for armor steel, although only five state DOTs require manufacturer representation during joint installation projects to ensure that proper construction procedures are followed. Tearing, snowplow damage, seal separation, and debris accumulation are the most common modes of joint failure. Bridge inspection protocols generally follow the NBI reporting requirements, with inspections performed every 1 to 2 years.

CHAPTER 8
CONCLUSION

8.1 SUMMARY

UDOT has increasing need for reliable joint treatments to prevent water ingress and subsequent deterioration of bridge components through the corrosive action of deicing salts and to ensure an adequate riding surface for the traveling public. Bridge deck joints are essential elements in bridge structures; they are used to protect the edges of the concrete deck, seal the joint openings, and accommodate concrete deck movements. The effect of a failed bridge deck joint can be costly because, if a failed joint is not repaired or replaced, the substructure components may be seriously damaged due to the intrusion of damaging substances through the joint openings. UDOT funded this research to specifically investigate the performance characteristics of each type of joint available for use on concrete bridge decks.

Research on bridge deck joints was performed to evaluate several types of commonly used joints and their primary functions and movement ranges. Eleven reports on joint performance published by DOTs and universities were reviewed in order to obtain information on joint and joint header performance problems commonly encountered by state transportation agencies. In addition, five reports related to in-house experiments performed by UDOT from 1992 to 1999 on bridge deck joints were identified and reviewed. ASTM standards pertaining to quality assessment of joint materials were studied and summarized, and recommendations for the design, installation, and maintenance of bridge deck joints and anchorages were compiled. Finally, a nationwide questionnaire survey of state DOTs was conducted to investigate the state of the practice concerning concrete bridge deck joints.

8.2 FINDINGS

Bridge deck joints can generally be classified as open joints or closed joints. Butt joints, sliding plate joints, and finger joints are categorized as open joints. Because open joints allow water, debris, and deicing salts to pass through the joint openings, the joints are usually installed with troughs, which are used to collect the substances that pass through the joint openings. Open joints lost their popularity in the 1960s and were rapidly replaced by closed joints as the runoff of deicing salts applied during winter became an increasingly important consideration. Six types of closed joints are commonly used, including poured seals, asphalt plug joints, compression seals, strip seals, reinforced elastomeric joints, and modular elastomeric joints.

The literature review performed in this research suggests that compression seals are most commonly used to accommodate movements less than 2 in. Before being approved for use, the seal material should be tested according to ASTM D 3542. To avoid snowplow damage to the seal, the seal should be set between 0.125 in. and 0.156 in. (5/32 in.) below the deck surface. The seal should be sized in a working range of 40 percent to 85 percent of its uncompressed width to ensure that positive contact pressure is exerted against the joint faces at all times. Steel armor angles should be installed with compression seals to protect the edges of the concrete deck. The armor angles should be repainted periodically to prevent the steel from rusting. The seals should be continuous across the bridge deck and should reach high enough into the parapet sections to prevent accumulated snow from leaking over the top of the joint. In addition, a lubricant conforming to ASTM D 4070 should be applied to facilitate installation.

For joint movements less than 4 in., the literature review and the survey results indicate that strip seals are the most commonly used. A sample of the strip seal should be subjected to the tests outlined in ASTM D 5973. Strip seals should be installed as continuous pieces across the width of the deck and set high enough in the parapets to ensure watertightness. The seals should be set between 0.125 in. and 0.156 in. (5/32 in.) below the deck surface to prevent the seals from being damaged by snowplow blades. A lubricant conforming to ASTM D 4070 should be applied during installation.

Reinforced elastomeric seals are also designed to accommodate movements up to 4 in. However, performance reports available in the literature suggest that these joints perform unsatisfactorily. More than 99 percent of the tested joints were prone to snowplow damage and leaked extensively. Leakage occurred between the joint and the concrete substrate and between the butt joints where the seals were spliced. Modular elastomeric joints designed to replace finger joints for accommodating movements more than 4 in. also experienced serious leakage problems and snowplow damage. Bridge engineers currently prefer using finger joints with troughs rather than reinforced elastomeric joints or modular elastomeric joints for movements greater than 4 in. due to the above-mentioned problems. To maximize the performance of finger joints, engineers should ensure that the joint material has adequate structural properties and that the troughs are installed properly. Finger plates should have adequate stiffness to avoid excessive vibration and should have sufficient tensile strength to avoid bending. The steel surfaces should be repainted periodically to avoid corrosion. The trough should be placed with a slope of at least 8 percent to prevent debris accumulation and should be cleaned at least once a year.

Tests and specifications published by ASTM may be used by transportation agencies to test the adequacy of joint materials of interest. Unfortunately, however, ASTM only presents test methods and specifications for poured seals, compression seals, and strip seals, including ASTM C 719, ASTM D 3542, and ASTM D 5973, respectively. Researchers have suggested modifications to ASTM C 719 to improve the characterization of poured seals proposed for use on bridge decks, with suggested modifications addressing specimen preparation, sealant curing, and testing. No research concerning the adequacy of ASTM D 3542 and ASTM D 5973 for evaluating compression seals and strip seals, respectively, was identified.

Although the installation of bridge deck joints is among the last tasks associated with bridge construction, the installation should not be rushed. In such cases, contractors sometimes fail to follow plan drawings and manufacturers' instructions. Furthermore, manufacturer representatives should be employed as appropriate to ensure that proper joint installation procedures are followed.

8.3 RECOMMENDATIONS

This research suggests that UDOT should use compression seals with steel armor angles to accommodate deck movements less than 2 in. and strip seals for movements less than 4 in. When a joint is damaged and needs to be replaced, the whole length of the joint should be replaced to avoid serious leakage problems. Before a seal material is permitted for use in the joint system, it should be tested according to relevant ASTM standards. Compression seals should be tested in accordance with ASTM D 3542, while strip seals should be tested in accordance with ASTM D 5973. The lubricant used for installation should conform to ASTM D 4070. When movements greater than 4 in. must be accommodated, finger joints with troughs are recommended. The trough should be placed with a slope of at least 8 percent and should be cleaned at least once a year or more often if needed. All steel materials should be painted in the shop and repainted regularly to prevent corrosion, and all joints should be set between 0.125 in. and 0.156 in. (5/32 in.) below the roadway surface to minimize snowplow damage. For a given deck repair or rehabilitation, adequate time should be allotted in the joint construction schedule to ensure proper installation of the joint system, including curing time for concrete headers, primers, joint materials, and lubricants, before the deck is opened to traffic. Manufacturer representatives should be present to inspect the installation process.

When UDOT conducts in-house experiments on bridge deck joints in the future, engineers should include more information about the bridge structures, including the anticipated deck movements, ADT, and design loads for the bridges, for example. Also, UDOT should establish a consistent evaluation program for investigating joint products during the approval process. The program should include quantitative measurements including, but not limited to, debris accumulation, adhesion and cohesion of the joint material, condition of anchorages and header materials, watertightness of the joints, condition of the concrete edges of the deck, deterioration of substructures, ride quality, noise level under travel, and general appearance of the joints. These experimental data should then be thoroughly documented in the resulting reports.

The questionnaire survey identified many important practices utilized by state DOTs for the design, installation, and maintenance of bridge deck joints. UDOT may greatly benefit by considering the recommendations of these states to avoid using the types of joints and joint headers that have not been proven reliable. The utilization of appropriate joints and joint headers should yield increased service lives with attendant reductions in costs. These important practices are outlined in this report for possible implementation by UDOT.

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